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NATURAL HISTORY OF THE TULARE KANGAROO RAT

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The Tulare kangaroo rat lives in the San Joaquin Valley of California, which is from 40 to 70 miles wide and extends for about 250 miles north and south between the Sierra Nevada on the east and the Coast Range on the west. The geographic range extends latitudinally for 200 miles from a point about 20 miles south of Bakersfield, Kern County, northward to the vicinity of Raymond, Madera County, on the east, and to near Tracy, San Joaquin County, on the western side of the valley (fig. 1). Altitudinally it ranges from about 100 feet above sea level on the floor of the valley to nearly 4000 feet in the Coast Range. The lower part of this range is chiefly grassland and lies in the Lower Sonoran Life-zone, as indicated by the presence of Fremont cottonwood (*Populus fremontii*), iodine bush (*Allenrolfea occidentalis*), and the San Joaquin cottontail (*Sylvilagus audubonii vallicola*). The upper part extends into the Upper Sonoran Life-zone where live oak (*Quercus wislizenii*), scrub oak (*Quercus dumosa*), digger pine (*Pinus sabiniana*) and the brush rabbit (*Sylvilagus bachmani*) are found. The Tulare kangaroo rat ranges to a higher altitude in the inner Coast Range than it does in the Sierra Nevada, probably because the arid climatic conditions required by it extend to a higher altitude there.

The Tulare kangaroo rat has been described and figured by Grinnell (1922). The myology of a related species is described by Howell (1932), and the skeleton and adaptive features of this genus are dealt with by Hatt (1932).

METHODS AND ACKNOWLEDGMENTS

Night observation was carried on by use of a spotlight (automobile headlamp) mounted on a tripod with a tilting and revolving top, and connected to a six-volt storage battery. The light made the mammals extraordinarily cautious when they first emerged from their burrows, but after a short time they appeared to be oblivious to it.

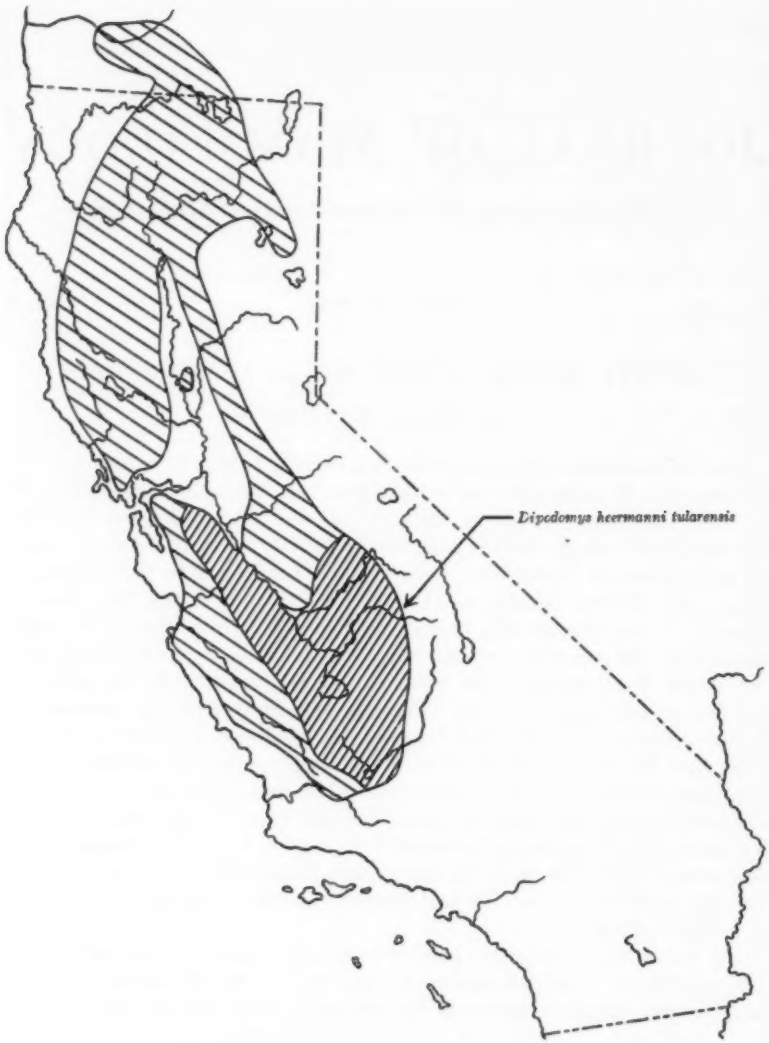

FIG. 1. Map showing geographic distribution of *Dipodomys heermanni tularensis* in relation to the range of the species *Dipodomys heermanni* as a whole.

Burrows were excavated usually by first digging a straight trench beside the burrow and to a depth slightly below that of the burrow at its deepest

part. From this trench the soil was excavated, maintaining a straight, vertical wall. While this method often involved considerable digging that did not help to expose the tunnels, it permitted an accurate plotting of the features of the burrow encountered. Additional excavations were made by merely digging and following the exposed tunnels, starting at the surface entrances and working toward the central part of the burrow.

To identify individuals fur was clipped from different areas on their backs and sides. The exposed dark gray base of the clipped fur contrasted with the surrounding brown hair of the back and sides, making it possible to identify individuals as far away as fifteen feet. All individuals captured in the immediate vicinity where night observations were made were given such identification marks. Individuals were also marked by clipping certain toes of the front and hind feet. Records were kept of the places where such individuals were marked, so that extent of movement could be determined.

Nine hundred hours were devoted to observation in the field at two localities, namely, Corral Hollow, 9 miles southwest of Tracy, San Joaquin County, and an area 4½ miles east and 1 mile north of Panoche, San Benito County. Field work was conducted in all seasons at each locality. A total of 214 hours on 34 nights was spent in detailed night observation of 37 kangaroo rat burrows and their occupants.

At Berkeley and Porterville, observations were made on animals housed in collapsible cages, measuring 12 by 14 by 24 inches, made of metal lath. This material was used because of its rigidity, and because its black color tended to cut down reflection so the animals could be more easily observed. Bottom trays for the cages were made of plywood. Each cage was provided with sand, a water bottle and a ten-inch exercise wheel.

I am indebted to my associates at the California Museum of Vertebrate Zoology for facilities and support given this study. I wish especially to acknowledge with gratitude my indebtedness to Professor E. Raymond Hall, the late Director, Professor Joseph Grinnell, and Dr. Jean M. Linsdale for much helpful advice and criticism in connection with my study. Also I have had other helpful suggestions from Professors Alden H. Miller and Charles L. Camp. To my brother, Virgil A. Tappe, I am grateful for help in connection with the field work.

BURROW SYSTEMS

Structure.—The Tulare kangaroo rat lives in burrows, which it digs, but these are often overlooked by the casual observer because there usually are no conspicuous permanent mounds of earth at the entrances (pl. 1a). This is especially true on steep hillsides. There, burrows may often be detected only by the presence of a few entrance holes in the center of a small area where the vegetation is sparse, or where the vegetation differs from that of the surrounding area. A newly dug tunnel, however, may have a relatively large mound of earth at its entrance (pl. 1 b), but when they are on steep hillsides, such mounds are soon obliterated by erosion. On level areas a slight, relatively permanent mound is built up over a period of years by the soil and food-refuse thrown

out of the burrow. There usually are no large mounds, even in level areas, because this rodent does not dig extensive tunnels as do some members of the genus. The average burrow excavated had about 35 feet of open tunnel, from two to three and one-half inches in diameter, with a few enlarged side pockets and chambers.

Burrows of *tularensis* can be classified as main and subsidiary, according to their structure and use. Seventeen main and 14 subsidiary burrow systems were excavated, seven at Corral Hollow and 24 near Panoche. Main burrows, in which the rats ordinarily spend the daylight hours, are used for resting, and as places in which to store food and rear young. As far as could be determined, one rat occupies each main burrow. The direction of the main tunnel seems not to be determined by the slope of the hill; in some burrows it tends to follow the contours, and in others it follows the slope. The main burrow is of simple construction, from six to 20 inches under the surface, and consisting usually of one main tunnel extending the entire length of the system with numerous loops and side branches, some of which end blindly with enlarged ends. It is in these that foods usually are stored and nests built. Other side branches inter-connect, and eventually lead to open entrance holes. Usually there are several tunnels dug from below to within one-half inch of the surface through which the animal can quickly dig or break to the surface. Joining the open tunnels are numerous old tunnels and pockets which are filled with soil mixed with hulled seeds and other refuse. Apparently the dirt used to plug these abandoned tunnels is that excavated in making new tunnels. Not all open tunnels are used; numerous side branches were found to contain old, undisturbed spider webs. Most of the burrows have one tunnel leading steeply downward to a greater depth than any other in the system. Such tunnels always end blindly and are without enlarged pockets. In one burrow excavated, such a side branch descended 41 inches below the surface. No regular use appears to be made of them, as the tunnels leading to such depths are usually obstructed with old, undisturbed cobwebs, and never were they found to contain nest material or stored food. It seems probable that they function as drains in times of heavy rainfall.

All main burrows excavated had a two-story arrangement of tunnels, except three which had a three-story arrangement. In contrast to this, Grinnell (1932, p. 310), in excavating three burrows near Panoche, found that *Dipodomys ingens* constructs a relatively simple, one-story system of tunnels, although the single burrow of *ingens* that I excavated had a three-story arrangement that branched and re-joined in a more complicated manner than any of the 31 excavated burrows of *tularensis*.

Main burrows of *tularensis* have from one to six entrances; three or four is the usual number. A two-acre plot contained 41 separate burrows, 5 with 1 entrance each, 18 with 2, 9 with 3, 7 with 4, and 2 with 5. Burrows having only one or two entrances probably were used for escape or temporary refuge. Grinnell (1932, p. 307) on three one-acre plots found 30 burrows of *Dipodomys ingens* with 2 holes each, 18 with 3 holes, 16 with 4 holes, and 7 "singles". Grinnell ruled out every single sequestered burrow that showed no evidence of being occupied, while in my survey of burrows of *tularensis*, all burrows were counted, as my experience with this species has shown that even what on the surface appear to be subsidiary escape burrows, may, in fact, be occupied. As a rule, all entrances are left open during the daytime, although a burrow on some days may have one or more entrances plugged from the inside. One or two entrances are used more frequently than any of the others. The openings thus used are those out of which dirt and food refuse are thrown.

Diameters of 31 main tunnel-entrances range from 42 to 81 mm, the average being 62 mm. As a rule, the more nearly vertical burrows are smaller in diameter. The openings into gently slanting tunnels usually were slightly higher than wide, although sometimes the reverse was true; openings into the more vertical tunnels usually were nearly circular. The greatest variation from a true circle was found in the largest opening, which measured 81 mm. high by 71 mm. wide.

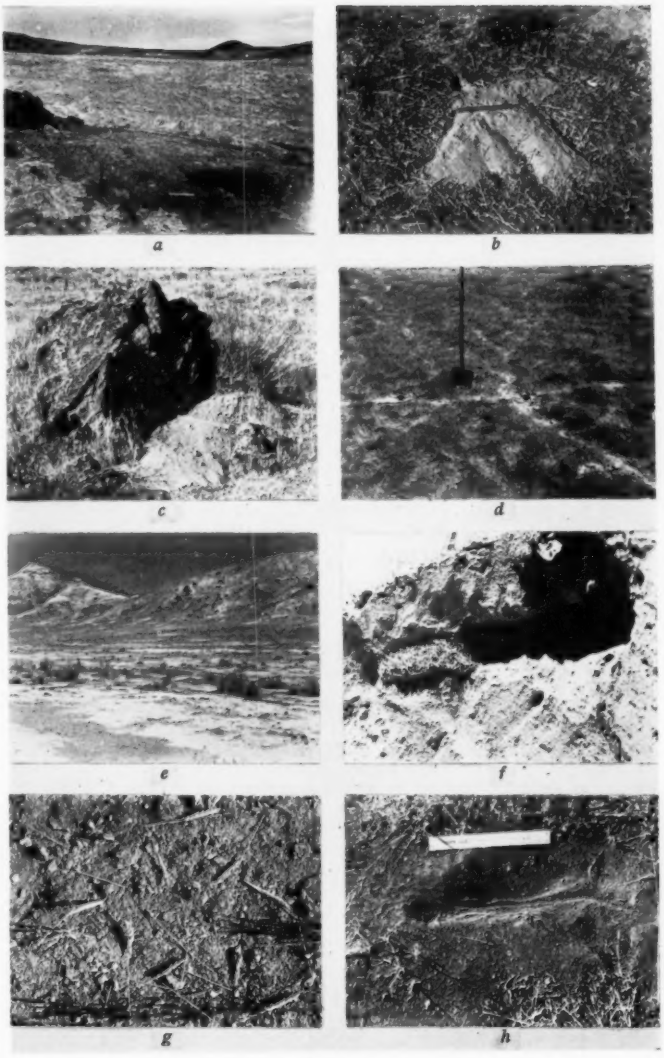

PLATE 1

a. Burrow of *tularensis;* Note that there is no large mound of earth. *b*. Mound of earth, larger than average, thrown from a main entrance to a burrow. Note the rodent's tracks in the loose earth. (Ruler shown is one foot long.) *c*. Mound of earth at entrance to a burrow of *tularensis* beside a rock. *d*. Surface runways radiating from a subsidiary burrow of *tularensis*. *e*. Habitat of *Dipodomys ingens* and *Dipodomys heermanni tularensis*. *Dipodomys ingens* occupies the level area in the foreground and *tularensis* the hillsides in the background, the line of demarcation between the habitats of the two species being just below the rocky area near the base of the hills. *f*. A store of seed of *Bromus rubens* in the blind end of a branch of a main tunnel. *g*. Heads of wheat cut by *tularensis*. Note that a head in the lower right center has been thrashed. Photograph by Joseph S. Dixon. *h*. A much used dust bowl. Note the tail mark in the loose earth. (Ruler shown is six inches long.)

The main entrances usually have a sloping tunnel leading down into the burrow system. In addition to the main entrances, at least one of which is usually more or less central, and one peripheral, in relation to the subsurface network of tunnels, there generally are additional entrances toward the periphery of the system. In every main burrow excavated, at least one entrance had a vertical tunnel from three to seven inches long leading to it. The vertical tunnel connected with the more nearly horizontal tunnel of the remainder of the burrow. These entrances never had dirt thrown from them, and were often more or less concealed under bushes or in grass. It was from such entrances, rather than from conspicuous main entrances, that the kangaroo rats often first made their appearance at night, although after their first appearance they usually used one of the main entrances in their trips to and from the burrow. This type of entrance probably should more properly be called an "exit", as it is used for this purpose much more often than as an entrance to the burrow.

The entrances to burrows often are shielded by large rocks or shrubs (see pl. 1c). One advantage of having a rock at an entrance is that if a rat is pursued by an enemy which it momentarily eludes by dashing under the rock, the rat can leave unobserved at the opposite end of the burrow while, say, a coyote is busy digging on the other side. A bush would similarly serve as a shield, but probably not quite so effectively. Once while I was excavating a main burrow, the occupant ran from it and disappeared down a subsidiary burrow whose entrance and exit were on opposite sides of a two-foot high rock. When I began digging at the entrance to the subsidiary burrow, the rat dashed from the exit and ran to another burrow. Because of my height I was able to look over the rock and see the animal as it left the burrow, but had a coyote or some other relatively small animal been digging at the entrance, the rock would have blocked its view so that the rat probably could have escaped unobserved.

Subsidiary burrows have a less extensive tunnel system, and are simpler in construction than main burrows. They usually have one, two, or three entrances opening into a single, relatively straight tunnel that may have one or more side branches. These side branches, as in the main burrows, sometimes loop back to rejoin the main tunnel, or may lead to an opening, or, as is usually the case, to a chamber just below the surface. These burrows ordinarily lack the deep, blind tunnels found in main burrows, but they often have enlarged side pockets. Apparently subsidiary burrows serve only for temporary refuges or as "duck-ins" when the animals become alarmed while away from their main burrows. None of the 14 subsidiary burrows excavated contained nest material, but most of them contained small amounts of food.

Surface runways.—Outside the main burrow a network of easily discernible surface runways radiate to subsidiary burrows and burrows of other individuals (pl. 1d). The floor of one is 2 to 2½ inches wide, hard and usually bare of vegetation. If the area has been heavily grazed by sheep, rats utilize the sheep trails. In that event there are only a few "rat made" runs around a burrow. In areas thickly populated by kangaroo rats, it is often impossible to tell just how many of the surface runways belong to any one burrow system, because all burrows, whether inhabited or not, are connected by a maze of surface runs. In isolated burrows the runs generally extend from 30 to 60 feet from the main burrow, with perhaps one or more runs extending for 150 or more feet to connect with other networks of runways about other burrow systems.

Location of burrows.—The Tulare kangaroo rat appears to prefer as a site for its burrow a place where the soil is well drained and of such a nature that it can be easily dug, where scattered rocks and shrubs are present, and where grass is short and sparse enough not to hinder locomotion. At Panoche this rodent was most abundant on south-facing hillslopes. There, as a result of direct exposure to the sun, the soil was drier and the cover of grass more sparse than elsewhere. It was also noted at Panoche and Corral Hollow that kangaroo rats were most abundant on the steeper hillslopes. Many of

these slopes, because of the intensive grazing by sheep coupled with the foraging of kangaroo rats, by autumn lacked cover other than scattered *Atriplex* bushes and a few large fragments of sandstone. At Corral Hollow one steep hillslope approximately one-fourth acre in area in one night yielded six rats caught in live traps, although the slope was practically devoid of vegetation. Holes of kangaroo rats were scattered so thickly over the face of the slope that it was difficult to distinguish the outlines of individual burrows. At the top of the slope, there was a relatively flat area with a cover of considerable grass. Observation at night showed that rats living on the hillside gathered food largely on this level area.

The Tulare kangaroo rat occurs also in large numbers where short grass is the only ground cover present. Therefore, shrubs or rocks, although used by the rats, are not required.

In parts of Panoche Valley, *tularensis* was found only on the hillsides; the more gently sloping areas extending down to the creek were occupied by the larger *Dipodomys ingens* (see pl. 1 e). The line of demarcation between the habitats of the two species at the base of the steep slope was so distinct that traps set 50 feet to either side of it yielded only one species. At Corral Hollow, where *ingens* did not occur, *tularensis* occupied the level areas as well as the hillslopes. This suggests that at Panoche the Tulare kangaroo rat was absent from the level plain because the larger *ingens* crowded it out, not entirely because of its preference for the hillside.

Nests and places of rest.—Of 9 nests found in the 17 main burrows excavated, 6 occupied the blind ends of the deeper tunnels, two were in pockets or enlargements in the sides of main tunnels, and in one rocky area a nest was found on the surface among rocks under a large boulder. Usually, the nest chamber is centrally located in the burrow system, from 12 to 30 inches below the surface of the ground. Depth probably is determined largely by soil conditions; the nest chambers in burrows are nearer the surface in rocky soil than in easily worked soil. The chambers are of various sizes and shapes, most of them being ovoid in shape and about 5 inches wide by 6 inches long by 4 inches high. Every nest chamber found had only one entrance.

Nest material, which covers the floor of the chamber to a depth of about one inch, consists of fine grass stems, fine grass roots and husks from grass seeds. The top and sides of the chamber are lined with loose material or left bare. Usually the husks of grass seeds are next to the floor where they support the grass stems and roots. The writer found the husks always moist, whereas the grass stems were usually dry, and the fine roots lining the nest quite dry. Possibly the husks absorb moisture that might otherwise be absorbed by the grass stems and roots were they placed on the moist soil. Occupied nests made of fresh material were found only in April and May. All nests examined in the autumn had become moistened throughout and showed no sign of recent occupation. Apparently the nest is used only for rearing young. Except when there are small young, the animals probably rest on the loose earth of the floor of the burrow or one of its branches or side pockets. The mild winters that occur in the range of this race, together with the insulating effect of the soil over the burrows, would tend to allow the temperature within the burrow to remain relatively uniform and comfortable.

FOOD AND STORAGE

Like other members of the genus, the Tulare kangaroo rat stores food within its burrow. This food may be used during inclement weather, at other times when the animal does not venture outside, and as a supplementary source of food in times of drouth when the surface crop of seeds may be much less than normal.

Rain and heavy fog apparently are the only meteorological conditions that confine this rodent to its burrow. Since this rodent experiences mild winters and few days of

heavy fog, it normally feeds on the surface as long as ample food is available, and seldom is it forced to subsist entirely on its underground stores. This offers an explanation of why the underground food stores of *tularensis* are small; the largest cache found in any one burrow weighed 157 grams. Most burrows contained considerably less than this. In contrast to this, Vorhies and Taylor (1922, p. 19) found that *Dipodomys spectabilis* stored relatively large amounts of food; the largest lot, from New Mexico, weighed 5750 grams (12.67 lbs.). They also state (pp. 18–19) that *spectabilis*, in southeastern Arizona, at least, relies largely on stored materials, except during the actual harvesting seasons (April or May, and September to November).

The Tulare kangaroo rat stores food in pockets in the walls or in the blind ends of the tunnels (pl. 1 f). Most of the stores in the Panoche area were from 4 to 20 inches below the surface, but one store, containing 33 grams of *Bromus rubens* seed, was about 29 inches below the surface in a pocket in the wall of a tunnel. The seeds in this chamber were moist and somewhat moldy. Most other stores, usually located close to the surface, were dry. There, greater circulation of drying air prevents molding. The nature of the soil and rapid run-off in this area usually prevent the small amount of moisture that ordinarily falls from penetrating deeply. Seeds of one kind generally are stored together, but occasionally stores are of mixed seeds. Vorhies and Taylor (*loc. cit.*) found a similar condition in regard to the food stores of *Dipodomys spectabilis*.

Dry seeds, green vegetation, and insects are eaten by *tularensis*. Of these three types of food, dry seeds probably are most important, especially in the localities studied. There, the seeds of the grasses *Bromus rubens*, *Bromus mollis*, and *Avena fatua* are used most. The amount of seed harvested by this rodent is indicated by the stores within its burrows. These stores do not constitute the total harvest, however, because many seeds are eaten above ground.

Green vegetation makes up a large part of the diet of this rat. Individuals were often observed to cut and eat the green stems and leaves of filaree, grasses, and other plants. Green vegetation is most plentiful during the winter and spring, but in some areas within the range of this subspecies certain green plants are available throughout the year. Bits of grass or other green vegetation often were found scattered about within the burrows, but large quantities or concentrated "stores" of this type of material seldom were found. Also, pieces of cut green vegetation often were found scattered along the surface runways. Grass seeds, such as are found stored within the burrows, seldom were found along the runways. This material is carried in the cheek pouches, and is seldom dropped. Even if it were dropped, it probably would be picked up again on the next trip as these rats seem to prefer seeds to green vegetation; they seldom waste seed material, whereas often only a small portion of the green vegetation cut may be eaten.

Judged from the amount and kind of food found inside the burrows and the amount and kind observed to be eaten outside, approximately 75 per cent of all plant food of this rodent consists of grasses and 25 per cent of forbs.

Insects probably constitute an important part of the diet of this rodent. Several rats in the wild were seen to capture insects at night. Caged specimens also captured and ate moths and beetles placed in their cages. Generally the head was the part of the insect first consumed, and often this was the only part eaten. Insects observed to be eaten by wild kangaroo rats were all of medium or large size and included moths, beetles, grasshoppers, and Jerusalem crickets.

An attempt was made to learn which kinds of plants near the rats' burrows were used as food. Specimens were collected of each kind of plant growing within a fifty-foot radius of a main burrow. The burrow was then excavated and plant material found within the burrow was identified. It was thus possible to learn which of the available plants had been utilized. Thirty-one species of plants were found growing around 17 main burrows excavated, remains of 21 of which (see tables 1 and 2) were found in the burrows.

ECONOMIC IMPORTANCE

Both areas studied were heavily grazed by sheep. Forage was sparse, parallel sheep trails a few feet apart lined the hillsides, and preventable erosion had set in at many places. Although the foraging activity of *tularensis* often noticeably depleted the vegetation along the surface runs and in small areas about the entrances to the burrows, it appeared that in the areas studied the grazing of sheep and their trampling out of plants

TABLE 1.—*Plant seeds found within the burrows of Dipodomys heermanni tularensis*

NAME	TOTAL AMOUNT	NUMBER OF BURROWS IN WHICH FOUND
	grams	
Bromus rubens	1739	13
Bromus mollis	186.7	4
Avena fatua	103.2	3
Lupinus (3 species)	63.0	2
Lotus (2 species)	29.4	3
Trifolium (2 species)	32.1	3
Calandrinia caulescens	7.3	4
Erodium cicutarium	863.5	15
Eriogonum sp.	Trace	5

TABLE 2.—*Plant material, other than seeds, found within burrows of Dipodomys heermanni tularensis*

NAME OF PLANT	TYPE OF MATERIAL	NUMBER OF BURROWS IN WHICH FOUND
Juniperus californicus	Leaves	1
Bromus rubens	Stems and green heads	3
Avena fatua	Stems and green heads	1
Lastarriaea chilensis	Flowering heads (dry)	9
Eriogonum angulorum	Flowering heads	4
Eriogonum fasciculatum	Leaves	3
Atriplex sp.	Leaves and stems	6
Lepidium nitidum	Green pods and leaves	7
Erodium sp.	Leaves and stems	7
Euphorbia serpyllifolia	Leaves and stems	2
Compositae	Fresh immature heads	3
Gutierrezia californica	Stems, leaves and flowers	8

was the major factor in holding the areas to their present low carrying capacity for livestock.

Because these rats are able to exist in large numbers where vegetation is sparse, heavy grazing of an area by livestock may not reduce much, if any, the carrying capacity of the area for kangaroo rats. If every bit of forage produced were needed by livestock, then the cutting of some of the available green forage and the harvesting of seeds by kangaroo rats might affect the carrying capacity of the area for livestock enough to make the rats of adverse economic importance. If so, the competition offered by kangaroo rats would seemingly increase as the acreage necessary to support each head of

livestock increased on an already overgrazed area. On a properly grazed range it is unlikely that the rats would decrease the carrying capacity of the range for livestock.

According to old settlers, in the area west of Porterville kangaroo rats were abundant before it was intensely cultivated and irrigated. Now only occasional rats are found there; one must go west, beyond the area of intense cultivation, to find kangaroo rats in abundance. The damage that they may do to cultivated crops is negligible, except where crops are grown adjacent to, or surrounded by, uncultivated land occupied by them, in which case the rats living there have access to the crops. For example, in a dry-farmed wheat field at the mouth of Caliente Creek Wash, Kern County, Dixon (MS), in May, 1918, found *tularensis* to be gathering the heads of growing wheat, the seeds of which were in the "milk" stage. He found these rats doing much damage, although not as much as jackrabbits, which also had invaded the field. The two kinds of mammals together destroyed at least 40 acres of one field in three weeks. Dixon further states that kangaroo rats continued to cut wheat stalks and shell out the grain after it had ripened, although the jackrabbits then had ceased to eat it (see pl. 1 g).

Harmful effects of the activity of *tularensis* probably are partly compensated for by its eating insects that are destructive to cultivated crops. During the outbreak of grasshoppers in the western part of the San Joaquin Valley in the spring of 1939, this kangaroo rat was observed to eat considerable numbers of this pest. In this instance, the kangaroo rats probably had no appreciable effect in limiting the insect population, but at other times the animal may be one of the important natural checks which help prevent outbreaks of this kind.

WATER REQUIREMENTS

The amount of free water required by the kangaroo rat is, under normal conditions, small. Because this rodent normally spends the daylight hours within the confines of its cool, and often moist, burrow, it can exist with less water than would be necessary for a diurnal species of the same size, other factors being equal.

Where this animal occurs, the annual rainfall ranges from about 5 to 14 inches; most of this is concentrated in the winter and spring. Generally, there is little precipitation from May to October, inclusive. Kangaroo rats are not dependent on surface water because often they live many miles from where there is any; neither are they dependent on subsurface water, for the water table often is many feet below the bottom of the deepest tunnel. Moisture in the food eaten, moisture in the soil, and dew are the available sources of free water for a large part of the year. Nelson (1918, p. 400) states that kangaroo rats (*Dipodomys spectabilis*) do not drink water, but obtain the necessary moisture through the digestive processes. Other authors, notably Howell and Gersh (1935, pp. 1–9), have commented upon the rôle played by metabolic water in kangaroo rats and other heteromyids, and from their work it seems that, under certain conditions, some members of this family depend upon metabolic water, together with that in the air-dried foods which they eat, to satisfy their moisture requirements. Howell and Gersh found that dry-fed kangaroo rats conserve the moisture in their excretory fluid by resorption of the water in it by the ducts of the renal papillae, and by the walls of the urinary bladder.

Vorhies and Taylor (*op.cit.*, p. 25) found that in the laboratory, *Dipodomys spectabilis* ordinarily showed an aversion to water. *Dipodomys heermanni tularensis* usually showed a similar aversion, but they would drink water under certain conditions; animals caged for two weeks without water or moist food took water out of a pan. In doing so, they stood on their hind feet, reached out over the water with their front feet, and skimmed the surface with their paws as these were drawn toward their bodies. They then licked the water from their paws as they rubbed them with a circular motion over

their mouths. Water bottles with tubes were regularly supplied, and the caged specimens often licked the hanging drops of water from the tips of the tubes. Kangaroo rats kept in a heated room, without water or succulent food, died within a few weeks. For example, five animals kept in dry cages in a heated room without water, and fed only dried wheat, corn and oats, died within three weeks, while others given a constant supply of water lived as long as 18 months.

Many times I have placed small jar-lids of water outside kangaroo rat burrows, but only twice did individuals drink from them. This suggests that the animals may occasionally drink from small puddles of rain water, but this was not observed. Some moisture is probably obtained from seeds left stored underground; seeds found deep in the burrow systems were usually damp, the husks being soft and flexible. In winter and spring, considerable moisture is obtained also from succulent grass, leaves and stems, which form a large part of the diet in these seasons. Insects furnish moisture and probably are an important source of water in the dry summer months.

Although these rats, under certain conditions, go to water to drink, they normally show an aversion to getting their fur wet. Two or three drops of water sprinkled on the nose of a caged rat as it was eating green grass caused it to jump backward three or four inches, pause a second, and then roll vigorously. The animal then resumed its eating. Again a few more dr ,s were sprinkled on it, whereupon it ran to the opposite end of the cage and started plowing up the loose sand in an almost frantic effort to dry itself. It rolled two or three times, followed this with a vigorous kick of the hind feet which sent the sand flying, and then rolled again. This cycle was repeated five times before the animal resumed eating grass.

ACTIVITIES

Times of activity on the surface of the ground.—The kangaroo rat is essentially a nocturnal mammal, so far as its activity above ground is concerned. Rarely has the writer seen members of this genus voluntarily emerge from their burrows in the daytime. On a clear day in early spring, he saw members of the species *Dipodomys nitratoides* leave their burrows as many as seven minutes before sunset.

Better to describe this diurnal activity, the following field notes of the writer for February 23, 1938 are quoted: "This evening reset my can-traps, using the same bait (rolled oats). It was close to sundown when I started putting out traps. While setting them, I heard a trap snap about 150 yards behind me. I went back and found I had caught a live adult *Dipodomys nitratoides nitratoides*. The sun was about five minutes from setting when the trap went off; I had set the trap not more than five minutes previously. Continued putting out traps, and just as the sun was setting I caught another of this species. By the time I had finished putting out all my twenty traps (about ten minutes past sundown), I had caught a total of four rats." This abnormal activity may have resulted from damage to food stores by heavy rains of a few days previously.

Dipodomys heermanni tularensis appears to be more strictly nocturnal than *D. nitratoides*. Once, when the writer watched adjacent burrows of the two species, *nitratoides* emerged five to twelve minutes earlier; even then the earliest *nitratoides* emerged six minutes past sundown.

Under normal conditions probab v light intensity is the most important single factor governing the time of emergence of *ularensis*. Repeated observations showed that on nights when the moon was not visible, adult rats usually emerged from their burrows as soon as it became quite dark after the sun had set. On the contrary, when the moon was full, or near that stage, and shining brightly at the time the sun set, they did not appear on the surface until the moon had almost disappeared in the west, even though this was in the early morning hours.

On one moonlight night, a kangaroo rat burrow was watched from sundown until

midnight; no mammal was seen to emerge. At 4 o'clock, about one hour before the moon was to set, watch was again resumed. About 20 minutes before the moon disappeared behind the hills to the west, the drumming sometimes made by kangaroo rats before emerging was heard. One and one-half minutes later a kangaroo rat emerged and began its foraging. On nights when the moon is considerably less than full, or when it is partly obscured by clouds, activity usually goes on as it does on nights when the moon is not visible. Evidently light intensity on a clear, full moonlight night is above the maximum tolerated by this mammal for normal emergence from its burrow.

The location of the burrow also affects the time of emergence of the occupant; when under a tree, beside a rock, or otherwise situated so that it may be shaded from the light of the sun or moon, the animal comes out earlier than from unshaded burrows. For example, a burrow under the east edge of a rock outcrop, or on the east slope of a hill would be first to come in the shadow of the setting sun, so that the minimum of darkness required by the occupant for emergence would, on a moonless night, occur earlier than it would at a burrow situated in the open or under the western edge of a rock outcrop. The occupant of one burrow at the base of a medium-size willow tree emerged, on the average, ten minutes earlier than did the occupant of an adjacent burrow in the open beyond the shadow of the willow. It was darker under the willow than it was in the open; the tree cast a definite shadow from the reflected rays of the sun which had dropped behind the horizon. After emerging, the rat moved about freely under the willow, but did not venture beyond the shadow until after a kangaroo rat in the burrow in the open had emerged and begun foraging.

On moonless nights, activity above ground in the open usually begins between 20 and 30 minutes past sundown; the occupants of 16 out of 21 burrows watched under such conditions first emerged at this time. Although some individuals may intermittently forage above ground throughout a dark night, repeated observations have shown that, as a rule, the majority of individuals forage above ground in two fairly well-defined periods in the early part of the night. For about 40 minutes after their first emergence a majority of the rats spend most of the time on the surface, unless they become alarmed and enter their burrows, where they remain for indefinite periods. After this forty-minute period, most of them enter burrows and remain there for as long as four hours. When they again emerge, the period of activity varies. Sometimes, it amounts to only a few minutes; at other times they are on the surface intermittently for as long as four hours, but generally after the second emergence, they are inactive for the remainder of the night.

On nights when a bright moon is absent for only a short time in the early morning hours, activity is concentrated in the period of greatest darkness. If the moon rises late, causing the period of greatest darkness to come in the early part of the night, activity is apparently no more concentrated then than it is in the early parts of nights that are without moonlight at any time.

Immature animals react to light conditions differently than do adults. They tend to be more erratic, and less cautious, often foraging in the moonlight when the adults do not venture forth.

Weather conditions also influence the time of activity above ground. Rain fell during all or part of three nights when observations were made. No surface activity was observed during the rains or immediately following them, even though the night in each case was moonless. When a light rain stopped in the early part of the night, the occupant of a burrow I was watching emerged only after the slick surface film of mud about the vicinity of the burrow entrance had dried. The evidence that the Tulare kangaroo rat is inactive on the surface during rain or heavy fog is supported by the fact that out of more than 300 trap nights when such conditions prevailed, no kangaroo rats were taken. Vorhies and Taylor (1922, p. 13) noted that *Dipodomys spectabilis*

spectabilis was inactive above ground on rainy nights, or when the ground was wet or covered with snow, but Dale (1939, p. 716) found that *Dipodomys heermanni saxatilis* was sometimes active on rainy nights, and he several times saw its tracks in the snow.

Sub-surface activity.—The Tulare kangaroo rat normally spends approximately twenty-three hours of each day within the confines of its burrow, but in a prolonged rainy spell, it may spend several consecutive days and nights underground.

These animals are more or less active within their burrows at all times of the year. The characteristic thumping made by members of this genus occasionally can be heard if one scrapes lightly around the burrow entrance. This thumping is more often heard after night has fallen, but at times it can be heard in the daytime, indicating that they may be awake, and more or less active, at all hours of the day.

The many plugged tunnels within the burrow system are evidence, also, that these animals carry on a certain amount of sub-surface activity, other than that involved

TABLE 3.—*Time spent above ground by a kangaroo rat on a night in October. Moon not visible, temperature moderate, breeze slight. Burrow in level, open country, with short, dead grass the only vegetation*

TIME OF EMERGENCE FROM BURROW	TIME OF ENTERING BURROW	TIME SPENT ON SURFACE	
p.m.	p.m.	min.	sec.
6:12:35	6:12:50		15
6:13:30	6:13:35		05
6:14:20	6:19	4	40
6:20:30	6:24	3	30
6:25:30	6:35	9	30
6:35:50	6:38*	2	10
6:50	6:53	3	00
6:54:30	7:01:30	7	00
9:20:30	9:23	2	30
9:29	9:30	1	00
9:57	10:01	4	00
		35	160
Total		37	40

* Alarmed by passing dog.

in the eating of stored food. On rainy nights, when the rats do not come out, they often push fresh earth, mixed with food refuse, from the entrances to burrows.

Foraging.—After first emerging from its burrow, the kangaroo rat usually remains for a short time close to the entrance. Then it takes alarm easily, and often, for no apparent reason, will make one or more dashes into the burrow. When finally assured that it is in no immediate danger, it begins its regular surface activity.

Where the burrow entrance is on a relatively level place, the animal forages in all directions from the main burrow, but if the burrow is located on a steep hillside, almost all foraging occurs on or above the contour on which the lowest burrow entrance is situated. The advantage of such a foraging habit probably is that when danger threatens, the animal can reach its burrow much more rapidly than if it had to run uphill.

Usually the animal forages along one of the numerous surface runways radiating from the burrow entrance, but often it leaves the runway and gathers food at some distance to one side. A considerable amount of food is gleaned from the ground, especially in the

late summer and fall. In the season when grass is ripening, most of the foraging consists of gathering the heads of grasses. To do this, the rat usually stands on its hind feet, gathers in a head of grass with its fore feet, and clips the stem with its teeth. It then settles down on its haunches and stuffs the material into its cheek pouches. Where the grass head is beyond reach, the stem may be cut off at a convenient height, and the head removed from the fallen culm.

Where kangaroo rats are abundant, their activity sometimes is sufficient to cause a decided change in the vegetative type about the burrows. In one area near Panoche, the grass on a hillside had given way around some of the burrows to a growth of red-stem filaree (*Erodium cicutarium*), so that the location of these burrows could be easily discerned from a considerable distance. The total area of cover so changed was slight, however, compared with the area that was unchanged.

Most of the seeds gathered are taken into the burrow, but some are eaten on the spot or are carried near the burrow and eaten just outside the entrance. Almost all of the succulent material gathered is eaten outside the burrow.

This kangaroo rat also gathers food from piles of refuse found around the entrances to the dens of the black harvester ant, *Veromessor pergandei* (Mayr). The material carried to the surface by the ants often contains large amounts of seeds that the kangaroo rat can use as food. Plant materials found in these piles include the seeds of *Bromus rubens*, *Bromus mollis*, *Lupinus* (two species), *Lotus*, *Trifolium* and *Erodium cicutarium* and the flowering heads of *Lastarriaea chilensis*. All these materials were found also inside the kangaroo rat burrows, and most of them probably are used as food.

Most of the insects found within the burrows of the kangaroo rat are sluggish and are easily captured, but some surface-dwelling insects, on the contrary, are exceedingly active, and to capture them, the kangaroo rat must act quickly and with dexterity.

Slow-moving insects, such as ground beetles, are merely picked up with the front paws and either stuffed into the cheek pouches, or eaten on the spot. In capturing rapidly moving insects, such as fluttering moths, the mammal follows the moving insect with quick, short hops, all the while reaching out with its front paws to grasp the insect when it comes within reach. Once a moth attracted to a flood light, landed on the ground about two feet from a rat. Immediately, the rat dashed for the moth by a series of short, quick hops, and appeared to pick up the insect. The moth escaped, apparently somewhat injured, and went fluttering over the surface of the ground. The kangaroo rat followed in hot pursuit and several times seemed to have captured the prey, only to have it escape again. After chasing it five or six feet, the rat finally captured the moth, hopped to the entrance of its burrow, nibbled at the insect for a few seconds and then entered the burrow, carrying the captured prey. In the laboratory live moths, whose wings had been clipped, were fed the captives. When a rat hopped within reach of a fluttering moth, it appeared to gather it in with both front paws and bite it immediately, although the movements were so rapid that it was difficult to tell exactly how the capture was accomplished. Several times the caged rats captured moths fluttering along two or three inches from the floor.

Dust bathing.—Almost every occupied kangaroo rat burrow has one or more places nearby where the animal can dust bathe. If a bush or ledge of rock is available, a dust bowl may be under it, but often the bowl is in the open along a trail or beside an entrance to the burrow. The dust bowls are of irregular shape and size, generally longer than wide, and, if much used, they are somewhat cupped toward the center (pl. 1 h). In some areas the soil is of such texture that almost any unvegetated spot can be used for dust bathing, and there is no specific place for this purpose. Where the soil is full of small rocks or is of clayey texture, the loose dirt thrown out of the burrow is used for dust bathing.

Dust bathing keeps the hair dry and sleek by removing excess oil secreted by the

dermal gland, and by removing excess moisture that may be on the fur; when animals in a cage cannot dust bathe, their fur becomes matted, as though wet, especially around the gland. The dermal gland is an elliptical, granular-surfaced area, about 6 mm. long and 3 mm. wide, running parallel to the axis of the body just behind the shoulders on the mid-line of the back. My observations tend to support Bailey's suggestion (1931, p. 248) that this functions as an oil gland for dressing the fur. This gland probably is important in keeping the hair and skin soft and pliable in the dry surroundings in which the kangaroo rats live. Bailey suggests also that the gland produces an odor by which individuals recognize one another. The secretion may be rubbed off the hair at the entrance of the burrow.

In the wild, the animals bathe at various times in the night, but usually only after they have foraged for awhile. This is especially apparent in the spring and winter, when often there is a slight dew on the grass and their coats are dampened by it. At these times, they make frequent trips to the dust bowls as they go about their work of gathering food. In dust bathing the animals roll on their hips or shoulders, but never so that they lie entirely on their sides or backs; either the front or rear parts of their bodies always remain upright. When they roll over on their shoulders, they usually push themselves forward with their hind feet, plowing up the dust with the sides of their heads and shoulders. When they roll over on their hips, they stretch their hind legs out behind. Occasionally, when dust bathing, they lie on their bellies and stretch both hind legs straight backward.

SANITATION

The feces of the Tulare kangaroo rat are black, or dark brown. A pellet usually is from five to seven millimeters long by two and one-half millimeters in diameter, and is rounded or pointed at each end.

The burrows of kangaroo rats always seemed odorless, and each trapped animal was clean and sleek. Feces were scattered throughout the burrows and along the runways on the surface; apparently, there are no special places of deposition. Feces are often mixed with grass seeds, husks and loose soil, with all of which the rats plug unused burrows. Approximately five per cent of one plug consisted of feces. Perhaps feces in the tunnels are regularly disposed of by their incorporation in plugs which later are thrust out of the burrows. Feces occasionally are found in the cheek pouches, along with seeds and other material, but no evidence was found that they are regularly carried from the burrow in this manner. When a kangaroo rat is busy stuffing his pouches, small pebbles and sticks are often put in, probably accidentally, along with food. The occurrence of feces in cheek pouches probably is to be accounted for in the same way.

In some food-stores, a few scattered fecal pellets were present, but some stores were free of foreign material of any kind. Nest chambers invariably contained more or less fecal material. In one, the floor of a nest was covered with feces in all stages of decomposition. This was an exception, for none of the other nests found had more than a scattering on the floor, little more, in fact, than occurred along the floors of the tunnels.

VOICE AND COMMUNICATION

The Tulare kangaroo rat produces two types of sounds that possibly are used for communication. A fluttering or rattling sound is occasionally made before the animal first emerges from its burrow, or when it is disturbed by an intruder excavating its burrow. The sound consists usually of one, but occasionally two, series of thumping notes, each series lasting from one and one-half to two seconds. Where there are two series, they are separated by an interval of about three seconds.

I have most often heard this thumping while I was excavating burrows, a condition

under which the occupants were probably excited. Bailey (1905, p. 148) thinks that the sound is used as a signal of alarm, call note, or challenge. This kangaroo rat apparently does not produce this sound as frequently as some other species of the genus. According to Vorhies and Taylor (1922, p. 12), *Dipodomys spectabilis* invariably produces the sound before its first emergence into the open, and often on its appearance after it has been alarmed, although when the storage season has begun and the kangaroo rat is carrying loads of grass heads, or other material, into its den, it regularly comes out without preliminary signaling. *Dipodomys heermanni tularensis* occasionally makes this sound when first emerging from its burrow; it was never heard after the rat's first emergence, whether it has been alarmed or not. The animal never appeared sooner than thirty seconds after producing the sound.

Vorhies and Taylor (*op. cit.*, p. 11) credit Goldman with observing a kangaroo rat (*Dipodomys spectabilis*) produce this fluttering sound. The animal was standing with its forefeet on the ground and its tail extended. When making the sound, its hind feet were seen to vibrate. Several times I have heard my caged specimens produce this sound and once, in dim light, he was able to observe one in the act. It, like the one Goldman observed, stood with its forefeet on the ground, while its tail was extended in a curve backward. Its hind feet vibrated. It appeared that the hind feet were alternately lifted entirely from the ground, but this could not be verified.

Another sound is produced by the rapid scratching of the front feet. Although similar to the sound made by the hind feet, it is not as loud, and has more of a scratching, than a tapping quality.

In all observations at night, no free-living kangaroo rat was heard to produce a vocal sound. Price (*in* Allen, 1895, p. 213) states that kangaroo rats foraging in the moonlight at Willcox, Arizona, made low chuckles at intervals. The writer has occasionally heard caged *tularensis* make such sounds, but only when disturbed. Kangaroo rats, when taken from live traps, occasionally produce a plaintive, low pitched, rattling squeak, while struggling to escape from a person's grasp. A similar squeak often is made by the female when placed with a caged male in the breeding season. A high pitched squeak was once made by a female when a male, with whom she was temporarily placed, bit her on the flank.

SENSES

Hearing.—The sense of hearing seems to be well developed in the kangaroo rat. It is probably this sense, together with the sense of sight, and possibly smell, that enables it so quickly to detect the approach of an enemy. The external ear is small, as it often is in a fossorial mammal, but the auditory bullae are large and probably compensate for the lack of a large external ear.

The one instance in which I had an excellent opportunity to judge the hearing ability of this species under natural conditions, indicated that this sense is keen. With the aid of a floodlight, an adult female was watched foraging. She hopped about in the sparse cover of grass beside her den, about fifteen feet from the base of a low, broad, densely leaved willow tree. She was sitting about twenty-four inches from an entrance, eating, when, suddenly, she gave one leap and disappeared down the burrow. Approximately one second later, silhouetted against the moonless sky, the dark form of a bird, probably a barn owl, appeared over the top of the tree and about fifteen feet above the spot where the rat had been. The fact that the kangaroo rat was alarmed before the bird came into view makes one wonder if the rat heard the sound of the bird's wings, although no sound was audible to the observer, even when the bird passed almost directly overhead. From the rate of speed at which the bird was cruising, it was estimated that it was fully thirty feet distant when the rat took alarm

Sight.—This rodent, at night, quickly detects any rapid movement within its field of vision. When observing at night, it was necessary always to move slowly and deliberately when the rodent was within thirty feet; otherwise, any quick movement would often send it scurrying to its burrow. Beyond thirty feet, the rat paid less attention to movement, and at seventy-five feet it rarely took alarm from this cause.

Because relatively tall brush, weeds, and grass often obscure their view while foraging, eyesight probably plays a minor part in guiding the fleeing rats to their burrows. Sight may aid them where the vegetation is low enough to enable them to look above it at the highest point of each jump. However, after arriving in the vicinity of the burrow, the rat probably uses its eyesight to guide it into the actual entrance. Once when James F. Ashley (MS, 1939) was attempting to capture a rat that was at large in a room, it quickly dashed across the room, and struck a small circular, black spot on the side of a cardboard box on the floor. The impact threw the rat back a foot or more, and dazed it. Apparently, it mistook the black spot for an entrance to a burrow.

Smell.—There is evidence that the sense of smell is highly developed in kangaroo rats. Caged rats often bury seeds and dry food to a depth of one-half inch or more, to be dug up and consumed at a later date. Such buried material probably is located through the sense of smell, rather than by the rat's remembering the exact spot where it was buried. On several nights rolled oats were buried by the writer in a cage at a depth of as much as one inch. When placed in the cage, a kangaroo rat usually had dug up such buried food by morning. No evidence was obtained to indicate that the sense of smell aids the rat in detecting enemies.

LOCOMOTION

Method.—The kangaroo rat moves about, principally, by a series of leaps with its highly developed hind limbs. Its fore limbs are sometimes used for locomotion when it moves only a short distance, as when gathering food scattered on the ground. Then the fore limbs are placed on the ground to support the body, while the hind legs are simultaneously brought forward; the tail is dragged loosely behind, or held only slightly off the ground in this type of movement. Several such hops may be taken to move the body forward four or five inches. In this type of progression, the entire sole of the hind foot is placed on the ground at the conclusion of each hop, whereas, in the usual bipedal method of hopping, only the toes come in contact with the ground.

In moving leisurely, the animal ordinarily makes a series of quick hops, each about six inches in length, which carries the body forward in a straight line. In this type of locomotion, the tail is held off the ground, and is extended straight out behind, except that the distal third is bent upward.

When running rapidly, the bipedal method of locomotion is again used, but the individual hops are much longer, and the tail is waved wildly about, probably to keep the body balanced. In this type of locomotion, the body follows a zig-zag course, the direction of movement changing somewhat with each hop. The kangaroo rat displays remarkable alacrity in changing its direction of travel; it is able, at the end of one hop, to change its direction of movement almost ninety degrees, an ability that must be of definite advantage in eluding pursuers.

The lengths of the individual hops vary considerably, but usually they are not more than twenty-four inches; most are less than this. The longest hop measured, apparently made while the animal was moving at top speed, measured twenty-eight inches.

Speed.—A stop watch, registering in tenths of a second, was used to check the running speed of kangaroo rats. They were released and allowed to run to a burrow. Usually, they were started by a clap of the hands, or by attempting to recapture them. The distance between the start and the finish was measured in feet, while the time consumed was measured in seconds (table 4). The top speeds attained in day and night checks were about the same, being 16.4 and 17.6 feet per second, respectively; 17.6 feet per

second is equal to 12.0 miles an hour. In each instance top speed was attained when the animal appeared to be thoroughly frightened. The speed of travel in ordinary foraging activities varies considerably, but when the animal is moving leisurely it is about two and one-half feet a second.

Endurance.—Kangaroo rats exhibit endurance in the performance of their normal activities. While foraging, and in harvesting and storing seeds, they move about almost constantly, often for considerable periods of time, without showing signs of exhaustion. Also, caged animals run leisurely on revolving wheels, apparently without becoming exhausted. One caged animal was observed to keep a wheel revolving for twenty-five out of thirty consecutive minutes. C. P. Richter (*in* Howell and Gersh, 1935, p. 2)

TABLE 4.—*Daytime and night-time speed trials of Dipodomys heermanni tularensis*

DISTANCE	TIME	FEET PER SECOND
	Day trials	
feet	*seconds*	
54	3.4	15.9
18	1.1	16.4
75	7.9	9.5
55	4.6	12.0
105	8.1	13.0
27	1.7	15.8
75	6.5	11.5
21	2.2	9.5
38	2.9	13.1
41	3.2	12.8
	Night trials	
31	3.1	10.0
27	2.2	12.3
16	1.1	14.5
21	1.7	12.4
33	2.9	11.4
25	1.9	13.2
37	2.1	17.6
41	3.2	12.8
20	2.5	8.0
52	3.6	14.4

found that the activity record of *Dipodomys* is quite variable, but that individuals may run on an exercise wheel as far as sixteen miles a night.

Their endurance when they exert themselves, however, is low. After running at top speed for fifty or seventy-five yards, when pursued, they show definite signs of exhaustion. If they cannot locate a burrow in which to dart, they may take refuge by hiding under a bush or, rarely, by "freezing."

METHODS OF ESCAPE FROM ENEMIES

To escape enemies, the Tulare kangaroo rat depends primarily on its agility and its ability to run rapidly. Usually it maintains from one to four escape burrows in addition to its main burrow. If pressed by some enemy, it normally runs to, and darts down, the nearest of these burrows in a surprisingly short time. Occasionally, if the animal is

hard pressed, it may enter the burrow of some other individual, should such a burrow be more convenient than one of its own. Usually, the owner of the burrow, if at home, forcibly ejected the intruder within 40 seconds from the time of his entrance. This length of time is probably sufficient to convince any pursuer that he has been foiled and to permit the rat to emerge in safety.

No individual of this subspecies has been observed to venture farther than forty feet from a burrow of its own, or one of some other individual, although trails connect burrows as many as one hundred and fifty feet apart, and lead one to infer that, at times, the rats venture farther than forty feet from a burrow.

If a kangaroo rat is inside a burrow while some enemy is also inside or is digging from without, the rat may dig or break through the thin crust separating some of the tunnels from the surface, and elude the pursuer. Several times, while excavating burrows, the occupants escaped in this manner, instead of leaving by one of several open entrances that were only a few feet distant.

Another method of escape is to "freeze." Once I released an adult rat in the daytime, and began to pursue it. Previously the entrances to all nearby burrows had been plugged. The rat appeared utterly confused, and darted first in one direction, and then in another, in a vain attempt to locate an entrance to a burrow. With the writer some eight or ten feet behind it in hot pursuit, it suddenly seemingly vanished. When located it was lying flat in the grass, its body tilted slightly to one side, and its tail outstretched. The only movement was that of rapid panting, and the wiggling of vibrissae. In this position the rat was difficult to see; the color of its body blended well with that of the dry grass in which it was hiding. It was not noticed until the observer was within six feet of it, and then the movement of the body, caused by breathing, first attracted his attention. The rat allowed the observer to walk up quietly and place his foot within three inches of its back, before it darted off in a bee-line to a burrow about fifty feet away, on the periphery of the group whose entrances had been plugged. The animal apparently had become oriented while lying quietly, and it knew just where to run to escape. This method of escape was never observed at night, but it probably is used in emergencies when the animal is hard pressed and far from a burrow.

BREEDING

Breeding occurs from February to August, inclusive. A specimen in the Museum of Vertebrate Zoology, taken on February 21, contained 4 embryos 7 mm. in length. This is the earliest breeding record for the subspecies *tularensis* available. Pregnant females have been taken in every month from March to August. The latest breeding record available for *tularensis* is that of a female with three embryos, captured August 27 near Lost Hills, Kern County. A specimen of *Dipodomys heermanni jolonensis* in the Museum of Vertebrate Zoology contained 4 four-millimeter embryos when taken on November 27, 1918. This is the latest breeding record available for the *heermanni* group; the earliest available record is from a specimen of *Dipodomys heermanni saxatilis*, now in the Museum of Vertebrate Zoology, that was taken January 5, 1929.

The highest percentage of pregnancy seemingly occurs in April. Of 11 adult female specimens taken in April, 9, or 82 per cent, were pregnant. Females breed before they attain adult size. One specimen in the Museum, recorded as having had three embryos, weighed only 57.7 grams, that is, about four-fifths that of a normal adult. Examination of its skull proved that it was immature.

PARTURITION

Each of two pregnant females, captured in the field, gave birth in the laboratory to a litter of young. The female taken on April 2, 1938, near Panoche appeared to be in

an advanced state of pregnancy. On the way to the laboratory, she prematurely gave birth to two young and upon arrival there the head and shoulders of a third had emerged. Apparently, it had remained for some time at this stage of parturition, for the exposed skin of the young rat had dried. The female was weak, and was unable to support her weight. This weakness was probably the cause of her inability to complete the birth of the third young. As I assisted by slowly pulling upon the young, the female contracted her abdomen every few seconds; after one minute of such pulling, the young had completely emerged. After this, the female became more active and was able to stand on her feet and hop slowly. Three hours later she gave birth, without aid, to a fourth young, after which she became weaker again and soon died. Examination revealed that she contained no further fetuses.

The premature young at birth weighed 2.3, 2.8, 2.9 and 3.2 grams. The two young born en route to the laboratory, when found, were free of after birth, and the third young was born without afterbirth. The fourth, however, was born with the amnion and a part of the placenta attached. The premature young were without hair, except for the vibrissae, which were about two millimeters in length and pale yellow in color. The hind legs and tail were folded forward close to the body, while the front legs were free. The hallux was present as a fleshy protuberance, much larger in proportion to the other toes than in the adult. Three of the premature young died within five hours; the fourth lived fourteen hours.

On April 14, 1939, a pregnant female, captured at Corral Hollow, was taken to the laboratory at Berkeley, where she was caged at 9:30 a.m. At 2:30 p.m. she gave birth to the first young, at 2:40 a second, at 5:50 a third, and at 6:04 a fourth. She appeared normal in every way, and showed no undue signs of nervousness, even when handled immediately before and after giving birth to young; she ate oatmeal a few minutes before giving birth to the first young. In constrast to this, Svihla (1930, p. 487) states that female red-backed mice (*Clethrionomys*) with newly born litters, are very nervous when disturbed.

The female retired to a nest box just prior to parturition, but offered no resistance when picked up and placed outside the box, where the actual process of parturition could be observed. In giving birth to the young, she stood hunched up on her hind feet, with her fore feet held just off the ground. Parturition was accompanied by a series of groups of abdominal contractions, each consisting of from six to eight contractions three seconds long. After completing a group of contractions, she rested quietly for thirty or forty seconds, when another group occurred. While the contractions were taking place, and when the young was already partly emerged from the vagina, she reached underneath and pulled at the young. When the young had completely emerged, she immediately turned to it and smelled it, after which she picked it up and carried it into the nest. The female then licked it, and fondled it with her front paws. Both young, of which the parturition was observed, were treated in the same manner by the mother; both were born head first.

GROWTH, DEVELOPMENT AND BEHAVIOR OF YOUNG

The young rats were watched and photographed, and changes in growth were recorded at regular intervals (see figs. 2 and 3, table 5, and pl. 2 a-g). At birth, they weighed 3.40, 3.50, 3.80 and 3.90 grams. Except for a decrease when 17 and 18 days old, and another decrease when one month old, they gained steadily in weight. When born, the tail and hind legs were bent forward and pressed close to the under side of the body. The hind limbs were about one-third longer than the front ones, and only slightly heavier, whereas in the adult kangaroo rat they are approximately two and one-half times as long. At birth the tail was relatively short, slightly more than one-half the length of the head

and body, whereas the tail of the adult is almost one and one-half times as long as the head and body. For the first five days the tails of the young were semi-prehensile; when the undersurface was touched with a probe, the tail was curled part way around it. During the first 17 days the length of the head and body almost doubled, and the length of the tail and the length of the hind feet tripled. At 17 days of age the hind feet were about three-fourths the length of those of the adult, the body about one-half, and the tail about one-third. When the young were about sixteen days old, the lengths of the tail and body were increasing at approximately the same rate, but after one month, the length of the tail increased faster than the length of head and body. At birth, the hallux was relatively large and appeared as a fleshy protuberance; the toe nails were short, soft, and bled if clipped. By the time the young were ten days old the nails could be clipped without bleeding.

The pinnae of the ears, which were laid over the meatus at birth, gradually became erect and by the fifteenth day their shape resembled that in the adult. The auditory and mastoidal bullae were relatively small, compared with the development of these parts of the skull of the adult. The external ears, which were closed at birth, opened on the sixteenth day, and the young, for the first time, reacted to the click of a camera.

At birth the eyes were about three millimeters in diameter and closed by a covering of thin skin, through which the pupil appeared as a pink dot about one millimeter in diameter. A shallow horizontal groove, which crossed the center of the upper half of the eye, marked the point of future separation of the eyelids. On the fourteenth day a one-half millimeter break near the middle of this groove showed that the right eye of the male was beginning to open. By the fifteenth day the eyes of the three females, and the left eye of the male had opened; the right eye of the male opened on the sixteenth day. When in the open position, the eyelids were held about one-half millimeter apart at the widest point; they were not spread wide apart, as in the adult.

Newly born rats had prominent, unpigmented vibrissae which at that time apparently are the most highly developed of the sense organs. If they are functional as tactile organs at this early age, they probably aid the young rats in locating the mammae of the female. It may be that the sense organs reach functional maturity in the order of their use; the location of the nipples of the mother is probably the first direct action taken by young rats.

The upper incisors of the male and the two largest females broke through the gums on the eleventh day. In the smallest member of the litter the lower incisors appeared on the eleventh day and the upper incisors on the twelfth. On the eighteenth day the color of the incisor teeth had changed from a pearly white to a dingy yellow. This possibly was associated with the concurrent change from a milk to a partly solid diet.

The external genitalia of male and female could be differentiated first on the ninth day by the fact that in the male a swelling appeared on either side and a reddened ridge extended back from the prepuce. The swellings and ridge were lacking in the females.

When born, the young were moist, but they dried within a few minutes. The skin was bright pink, wrinkled, and hairless. Cranial sutures and blood vessels, especially the femoral, caudal, and the vessels on the top of the head, were clearly visible through the thin skin. At 22 hours of age, a faint darkening on the rump and shoulders indicated that pigmentation had begun in the developing hairs. By the fourth day, pigmentation had spread over the head, back, and on the tail; the limbs were the last parts of the body to become pigmented. The parts of the skin that have white hair in the adult remained unpigmented in the young. In *tularensis*, pigmentation apparently begins to set in at an earlier age than in *Dipodomys spectabilis*; Bailey (1931, p. 255) says that the backs and heads of the latter began to darken at three days of age. In *tularensis* the dead, outer layer of skin began to scale off on the fourth day. Pigmentation continued to grow heavier over the entire dorsal region so that by the sixth day the cranial sutures

could no longer be seen, and on the seventh day pigmentation began to appear on the soles of the hind feet. Unpigmented skin on a swollen area on each side of the nose,

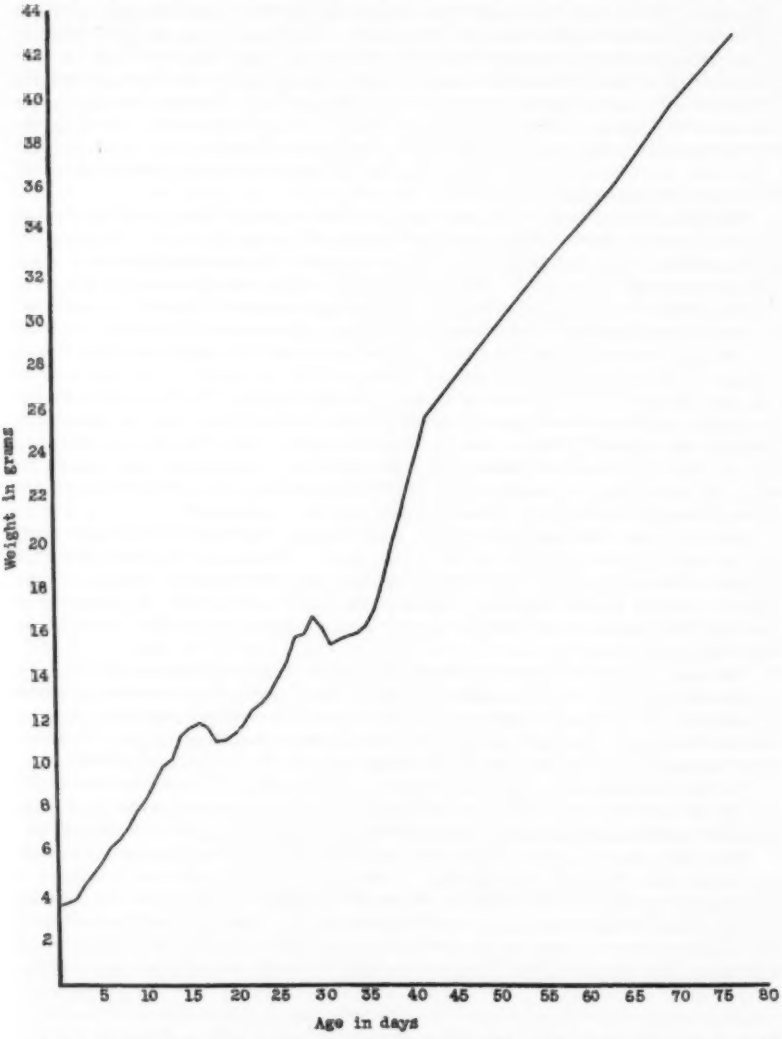

FIG. 2. Graph showing increase of weight in young *Dipodomys heermanni tularensis*.

where the vibrissae arise, remained a bright pink, similar to the color of the skin at birth, while the remainder of the unpigmented skin had by the seventh day become a dull pink.

As dorsal pigmentation progressed, the dermal gland appeared as an elongate, smooth-surfaced, unpigmented spot on the mid-line of the back; it did not have a roughened surface as in adults.

Except for the vibrissae, the newly born young were naked. On the third day, fine hair appeared on the back and top of the head. By the ninth day the pigmented areas of the skin were thickly covered with the fine, dark gray-brown hairs of the juvenal pelage; the unpigmented areas of the body were less densely covered with fine white

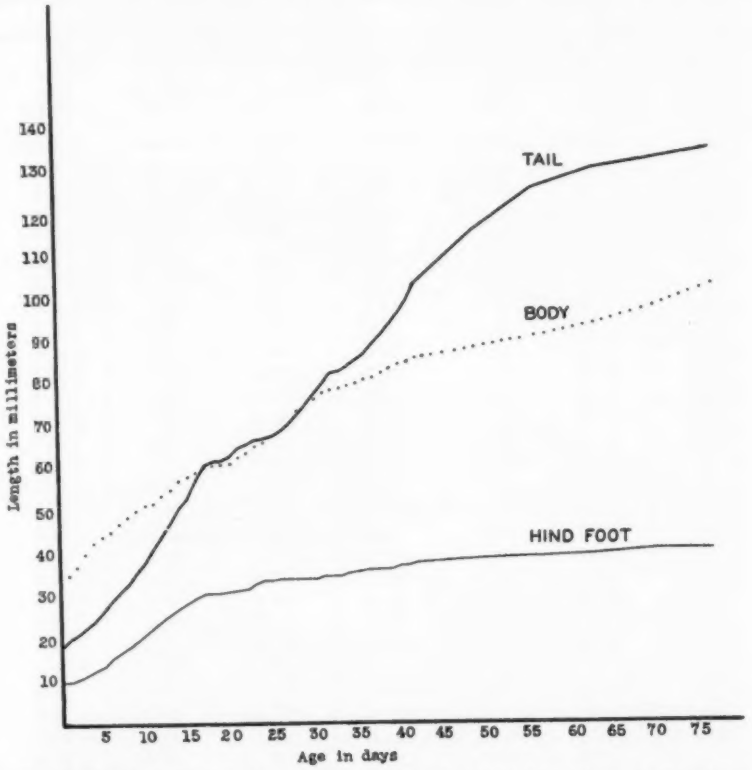

FIG. 3. Graph showing linear growth of body, tail and hind foot in young *Dipodomys heermanni tularensis*.

hairs. The dark and light areas of hair in the young rats corresponded to the same colored areas on adults. By the ninth day the distal part of the tail was covered with fine, short hairs for a distance of six millimeters back from the tip, but the remainder of the tail appeared hairless to the naked eye. On the twelfth day the brown-tipped hairs of the postjuvenal pelage appeared on the top of the head. By the fourteenth day the new hairs appeared on the shoulders, and by the fifteenth day the new hairs were thinly scattered over the back and rump. By the nineteenth day the new pelage had almost

replaced the darker juvenal pelage on the entire dorsal part of the body. When two months old, the rats appeared much like adults, except that the pelage on the back and hips had more of a grayish cast.

Cheek pouches at birth were shallow, crescent-shaped folds in the skin. These gradually deepened, until on the nineteenth day they were 10 millimeters deep.

The most common sound emitted by the young rats was a "buzzing" squeak, made with the mouth closed. This was heard from their birth until the nineteenth day, usually when they were separated from their mother, or when hungry. When the young

TABLE 5.—*Average weight and measurements of the members of the litter of Dipodomys heermanni tularensis kept in captivity from April 14, 1939, to June 30, 1939*

AGE	WEIGHT	BODY LENGTH	TAIL LENGTH	TOTAL LENGTH	HIND FOOT LENGTH	EAR LENGTH
days	*grams*	*millimeters*	*millimeters*	*millimeters*	*millimeters*	*millimeters*
birth	3.65	33.2	18.2	51.4	10.0	1.0
2	3.92	37.0	21.0	58.0	10.6	1.5
4	5.09	42.5	24.2	66.7	12.5	2.0
6	6.21	45.2	29.0	74.2	15.4	2.8
8	7.13	48.7	32.8	81.5	18.0	3.2
10	8.40	51.1	38.2	89.3	21.2	3.5
12	9.87	53.5	44.2	97.7	24.5	4.0
14	11.23	57.0	50.5	107.5	27.2	4.1
16	11.80	59.0	57.2	116.2	29.5	4.6
18	10.97	60.7	61.7	122.4	30.5	5.3
20	11.35	61.0	62.5	123.5	31.0	5.5
22	12.35	63.5	66.5	130.0	32.0	6.0
24	13.10	66.0	67.0	133.0	33.5	6.5
26	14.55	68.5	68.5	137.0	34.0	7.0
28	15.85	73.0	72.0	145.0	34.0	7.0
30	16.15	76.0	77.0	153.0	34.0	7.5
32	15.50	78.0	82.0	160.0	34.5	7.5
34	15.85	79.0	83.5	162.5	35.0	7.5
36	16.95	80.5	86.5	167.0	36.0	7.5
38	19.80	82.0	91.0	173.0	36.5	8.0
40	22.70	84.0	96.0	180.0	37.0	8.0
42	25.55	85.5	103.0	188.5	37.5	8.5
49	29.15	88.0	115.5	204.0	38.5	8.5
56	32.75	90.5	125.5	216.0	39.0	9.5
63	35.85	93.5	130.0	223.5	39.5	9.5
70	39.70	97.5	132.0	229.5	40.5	10.5
77	42.75	102.5	134.5	237.0	40.4	11.5

were sixteen days old, they were placed outside the nest box, allowing the mother to remain inside. The young began to squeak loudly, but the mother paid no attention to them. After about one minute, a young female walked a distance of twelve inches directly to the box, and entered through the two-inch entrance. Two others followed within another a minute. After three had entered, the fourth crawled over to the box and began to encircle it, apparently looking for the entrance. After crawling to within one inch of the entrance, the young turned and crawled to the opposite side of the box, all the time squeaking lustily. After several minutes of wandering back and forth without finding the entrance, it became completely confused, and started to wander all

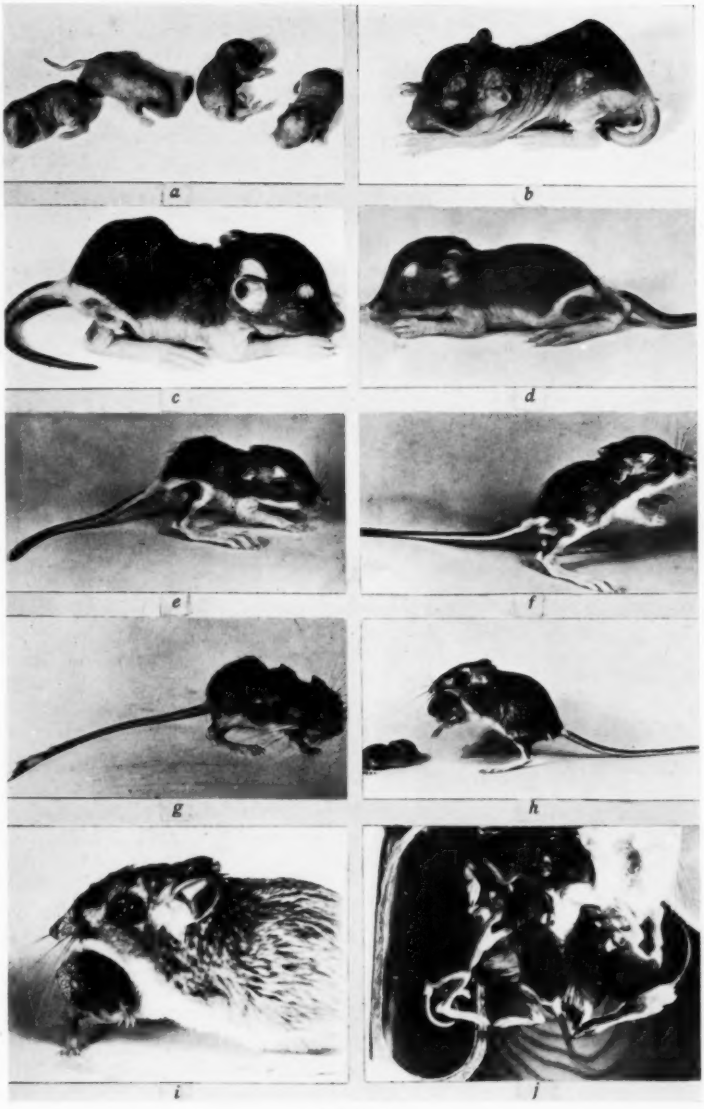

PLATE 2

a. A litter of *tularensis* one hour after birth; × ½. *b*. Age four days: × 1. *c*. Age eight days; × 1. *d*. Age 12 days; × ¾. *e*. Age 16 days; × ½. *f*. Age 20 days; × ½. *g*. Age 56 days; × ¼. *h*, *i*. Mother kangaroo rat carrying young. *j*. Kangaroo rat suckling her eleven-day old young; note that the young are lying on their backs. Photographed from below through a glass plate.

over the cage. After thirty minutes of such aimless wandering, during which time it squeaked continuously, it was placed in the nest with the mother, whereupon it immediately became quiet. Another sound made by the young was a somewhat musical "chirp," first heard on the seventh day and rarely thereafter. The third type of sound was a rattling squeak of low pitch and slight volume, heard from about the eighteenth to the twenty-fifth day when the young chewed at objects, or rarely when they walked about.

Newly born young apparently were unable to maintain a constant body temperature; when taken from the mother, they soon became cold to the touch. As they became older, they gradually acquired control of the body temperature and when one week of age they could be left in the open for an hour or more without apparent chilling. Possibly associated with this lack of control of body temperature was the behavior of the young when they were placed under a photoflood light to photograph them. They would squirm and kick violently until the warm light was applied, then they would instantly quiet down and go to sleep. By the time they were ten days old, however, the application of the light had the opposite effect, making them wriggle more violently.

The female spent most of the first day after the birth of her young in a corner of the cage, leaving them inside the nest. At irregular intervals she retired to the nest where she "brooded" her young for various lengths of time, usually for about 15 minutes, after which she would again leave them. When 18 hours old, the young were found nursing for the first time, but they may have nursed before this. After the first day the young were found attached to the nipples of the mother each time the litter was inspected, but on the seventeenth day they were found clinging to her only twice in ten inspections. The young clung so tightly to the nipples that when the mother was raised, the young were raised with her. While being suckled, the mother sat with her hind legs spread wide apart, allowing room for the young to get to her mammae. Two positions were commonly assumed by the young rats when suckling. In the position most used, they lay on their backs (see pl. 2 j), while in the other, they lay on their bellies and bent their heads backward to reach the nipples. Weaning appeared to be a gradual process that began when the young first started to take solid food on the seventeenth day and ended on the twenty-fifth day.

At birth, the young rats were almost helpless, but by the third day they were able to move about readily by crawling on their bellies; at this age their legs were not strong enough to support them. One individual, while attempting to climb an inclined plane, kicked violently simultaneously with both hind feet when unable to proceed with the usual belly-crawl; this was the first suggestion of bipedal locomotion. On the seventh day they were able to support the fore parts of their bodies with their front legs, and on the tenth day their hind legs became functional. They then were able to move slowly about by walking in a quadrupedal fashion, with the entire sole of the hind foot in contact with the ground. As the body moved forward, they alternately raised each hind foot, heel first, until the toes were the only part of the foot in contact with the ground. The tail was dragged. On the fourteenth day they were able to stand on their hind feet alone. In assuming this bipedal position, the rear feet were spread far apart, and the entire sole of each hind foot was on the ground. The front feet were held under the jaws, as is done by the adult. After this, a semi-bipedal method of locomotion gradually replaced the quadrupedal walk, until by the twentieth day, the young moved almost exclusively in this way. By the twenty-fifth day they were able to hop in the true bipedal fashion of the adult, but this method at first was used sparingly.

When the young were forty days old, they, with their mother, were taken to Porterville, in the San Joaquin Valley, where they were placed in an outdoor cage measuring 4½ feet wide, by 1½ feet high, by 6½ feet long. The wire bottom was buried under six inches of fine, sandy-loam soil. The adult dug a tunnel in which she and the young

stayed during the daytime. The young did not dig tunnels at this age (40 days), although they occasionally did dig small pits by scratching out the soil with their front feet. When two months old, they did more digging; often they would dig tunnels six or

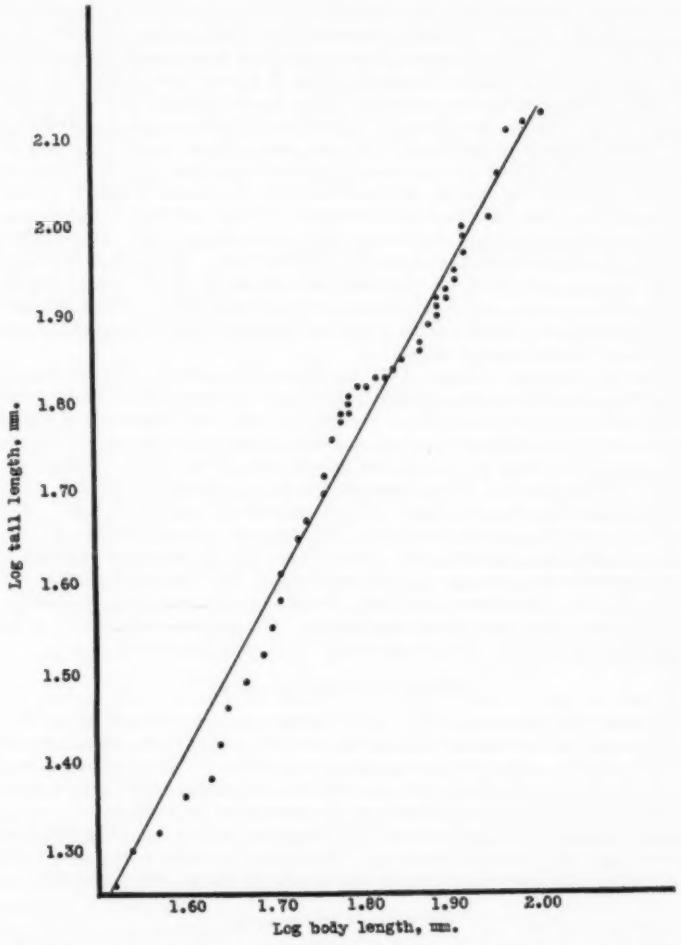

FIG. 4. Relative growth of the tail in *Dipodomys heermanni tularensis;* logarithmic plotting.

eight inches long into the soft floor of the cage. When 78 days old, the young died during a period of excessive heat. For several days previously, the temperature of the air had remained well over one hundred degrees Fahrenheit during the middle of the day.

It is possible that this was a factor in causing premature death, as the young, when found dead, were together in a tunnel, the ceiling of which was about three and one-half inches below the surface of the ground. This thickness of soil probably was insufficient to furnish the required amount of insulation.

Age at which young leave burrows.—The age of young taken in the field was calculated by comparing the weight and body measurements of such young, with that of young reared in captivity. Using this method of determining age, trapping data indicate that young rats normally leave the burrows in which they were born at about six weeks of age. The youngest appearing individual taken by me weighed 24.3 grams, but one specimen of *tularensis* in the Museum of Vertebrate Zoology weighed only 23.5 grams and measured 218 mm. (total length), 127 mm. (tail), 40 mm. (hind foot), and 12 mm. (ear). The corresponding parts of another museum specimen, whose weight was not indicated, measured 189, 104, 38, and 8 millimeters. No record is known to exist of a smaller specimen than this being taken in traps. Young rats may, under unusual circumstances, leave the burrow much earlier than at six weeks of age. Dixon (MS, 1918) found four young *tularensis* at the base of an *Atriplex* bush. One of them had been dead for a day or more, but the others were alive and squirming about. These rats did not yet have their eyes open, and moved by squirming on their bellies. Dixon believed that the mother had been trapped and the young had managed to squirm out of the nest and had wandered about in search of her.

Tail growth-coefficient.—Huxley (1932) has derived a formula for determining relative growth rates. In this formula, expressed $y = bx^k$, y is the magnitude of the differentially-growing organ, x is the magnitude of the animal minus the magnitude of the organ, b is a constant of no biological significance, and k, a constant, is the ratio of the relative growth-rate of the organ to the relative growth-rate of the body. Huxley (*op. cit.*, p. 10) says of this formula, "if the logarithms of the magnitudes are plotted, we should expect a straight line, from the slope of which the value of k can be read off." In order to see how closely the growth of the tail of the kangaroo rat approximates this formula of constant differential growth ratio, a curve was made by plotting logarithms of the linear tail growth measurements against logarithms of the linear body growth measurements (see fig. 4). This curve is a relatively straight line, showing that the growth of the tail of this rodent does approximate his formula. The growth-coefficient (k) of the tail of young kangaroo rats is 1.73, as calculated by Huxley's method.

METHODS OF CARRYING YOUNG

The mother kangaroo rat usually moves a young one by picking it up by the back with her mouth and holding her front paws under its belly to help support the weight (see pl. 2 h and i). After lifting the young, the adult moves by hopping on her hind feet. In contrast to this, Hall (1928, pp. 255–256) and Svihla (1932, p. 13) report that young *Peromyscus* are carried belly side up in the mouth of the mother.

Another method of moving young involves dragging them as they cling tightly to the nipples of the mother with their mouths. Young also are carried thus by *Peromyscus* (Svihla, 1932, p. 13), by squirrels and by other rodents (Lang, 1925, pp. 18–24).

POPULATION MOVEMENTS

Emigration of young.—At Corral Hollow, in the late summer of 1938, a level area of about four acres, situated among the low hills, for some unknown reason contained many abandoned kangaroo rat burrows. Poor drainage might have been the cause, as the area was situated in a pocket between the hills, and numerous outcroppings of rock around the margin suggested that bedrock was near the surface. From the early part of September until the fourteenth of October, traps were set in this area at weekly in-

tervals, but kangaroo rats were not caught. On October 21, ten traps in this area yielded three half-grown kangaroo rats. Subsequent trapping in the area yielded nine more immature rats, but no adults. It seems possible that the young rats were crowded from the burrows in which they had been living, and finding no kangaroo rats in the level area described, attempted to establish themselves in the abandoned burrows there.

Extent of individual movements.—Individual kangaroo rats, within their lifetime, may migrate considerable distances. One hundred and twenty-nine individuals were live-trapped, given identification marks, and released. In subsequent trapping over a period of from one to two years, 49 were recaptured from one to 10 times. Most of the recaptured individuals were taken within one-fourth mile of the point of original capture, but one adult female, captured and marked on February 15, 1938, was recaptured on October 5, 1939, approximately two-thirds of a mile from the place where first taken.

ANIMAL RELATIONSHIPS

In trapping on areas where the Tulare kangaroo rat is abundant, one seldom catches any other kind of small mammal. At Panoche, I purposely trapped such an area, covering about twenty acres, with the aim of catching any inhabitants other than kangaroo rats. Traps were set under bushes, in thick grass, and at other places remote from rat burrows and trails. Two hundred trap nights yielded only 5 *Peromyscus maniculatus gambeli*, 2 *Onychomys torridus tularensis*, 2 *Perognathus inornatus*, and 18 *Dipodomys heermanni tularensis*. Evidence gained from night observations carried on in places thickly populated by kangaroo rats, also indicates that other small mammals are scarce in such places.

This relative scarcity of other small mammals probably was caused in part by the competition offered by sheep and by kangaroo rats in utilizing the available forage. Just after the seeds ripen, the kangaroo rats lay in small stores of food on which they can draw, if necessary, in parts of the year when the surface food supply is depleted. In some instances the combined effect of grazing sheep and the cropping of seeds by kangaroo rats when they are building up their stores leaves the ground almost depleted of vegetation. This, together with the fact that kangaroo rats feed more or less throughout the year on what they can glean from any remaining vegetative cover to supplement their already stored supply of food, leaves little in the way of plant food to be gathered by other mammals. The scarcity of other small mammals in areas of sparse vegetation where kangaroo rats are abundant probably is caused in part also by the lack of cover suitable for protection from their enemies. Because kangaroo rats are able to run quickly to their burrows when danger threatens, they are better able to exist where vegetative cover is sparse than are some of the less agile mammals.

Various animals, other than the rats themselves, use kangaroo rat burrows as places of refuge or shelter. A pocket mouse, *Perognathus inornatus*, was driven from one of the 31 burrows excavated. In the same locality, one kangaroo rat burrow which was under observation, was taken over and enlarged by a ground squirrel, *Citellus beecheyi*; the squirrel enlarged and followed downward the tunnels leading to the two main entrances of this burrow. The squirrel apparently took complete possession of the burrow, as the rat was never seen again.

Horned toads (*Phrynosoma blainvillii*), blue-bellied lizards (*Sceloporus occidentalis*), brown-shouldered lizards (*Uta stansburiana*), and gopher snakes (*Pituophis catenifer*) were commonly found within the burrows of this rat, and once a rattlesnake (*Crotalus viridis*) was found in a store of grass seeds in the blind end of a tunnel.

Various invertebrates were found in the burrows. These included sowbugs, millipeds, centipedes, scorpions, spiders, Jerusalem crickets, beetles, and ants.

Owl pellet analysis shows that at Panoche the kangaroo rat, especially *tularensis*, is preyed upon heavily by owls. A total of 103 owl pellets, probably for the most part

from barn and great horned owls, were analyzed, and the numbers of mammals determined by counting the left lower jaws. The following animals were represented in these 103 pellets: *Ammospermophilus nelsoni*, 1; *Thomomys bottae*, 8; *Perognathus inornatus*, 18; *Dipodomys heermanni tularensis*, 55; *Dipodomys ingens*, 19; *Dipodomys nitratoides*, 15; *Reithrodontomys megalotis*, 3; *Peromyscus maniculatus gambeli*, 17; *Neotoma lepida*, 4; *Microtus californicus*, 3; *Mus musculus*, 6; valley quail, 1; other birds, 1; insects, 18.

Numerous coyote diggings about kangaroo rat burrows suggest that these mammals prey upon kangaroo rats. In one instance, a kangaroo rat nest which had been built under a rock had been torn out; tracks in the soft dirt about the burrow were made by a coyote. Other enemies probably include the kit-fox, rattlesnake, and gopher snake.

LENGTH OF LIFE

From information at hand, it appears that the Tulare kangaroo rat may normally live at least two years. A female, taken on February 15, 1938, was recaptured October 8, 1939, nearly 20 months later. She appeared to be full grown when first captured, and when recaptured, she was active and appeared to be in good condition. Individuals have been kept in cages for as long as 18 months, even though such rats were already full grown when first caged.

SUMMARY

1. The Tulare kangaroo rat is a nocturnal rodent inhabiting the floor of the San Joaquin Valley and the surrounding foothills in central California.

2. Each individual usually digs one main burrow in which it spends the daylight hours and one or more subsidiary burrows that are used chiefly as places of temporary refuge at night when danger threatens.

3. Burrows are connected by a network of surface runways which radiate outward from the various entrances.

4. Food, consisting chiefly of seeds of grasses and of other plants, is stored in the burrows.

5. Although primarily a seed eater, this rodent in the winter and spring consumes large amounts of green grass and other plants. It eats about 70 per cent of the species of plants which grow about its burrow; of the species eaten, an estimated 75 per cent are grasses; 25 per cent are forbs.

6. The breeding season extends from February to August, with the highest percentage of pregnancy occurring in April. The number of embryos varies from two to five, with an average of 3.7.

7. When the moon is full, or near that stage, and shining brightly, adult rats seldom forage on the surface. Young rats are less cautious, and may be abroad at any time of night. These rodents are active above ground at all seasons; in periods of inclement weather, they remain within their burrows.

8. In order to keep their fur dry and sleek, kangaroo rats dust bathe in the loose earth thrown out of their burrow entrances or in special "dust bowls" situated on the surface near their burrows.

9. Locomotion is principally by leaping with the highly developed hind legs. When frightened, this rodent is able to attain a speed of as much as 12 miles an hour.

10. At birth the young are hairless and almost helpless, the eyes and ears are closed, and they weigh one-twentieth as much as adults. The eyes open on the fifteenth and sixteenth days; the ears open on the sixteenth day.

11. The mother transports the young either by picking them up by the back with her mouth, supporting them with her fore feet, and carrying them bodily, or by dragging them while they cling with their mouths to her nipples.

12. Nests are constructed of grass stems, grass roots and husks of grass seeds, usually in an enlarged pocket in the blind end of a tunnel. Most of the nests found were from 12 to 30 inches below the surface of the ground; one was on the surface beneath a large boulder.

13. Burrows in sandy, easily worked soil have deeper tunnels than burrows in rocky soil.

14. The senses of hearing and sight are keen.

15. Young rats normally do not venture from the burrows in which they are born until they are about six weeks old.

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TECHNIQUES FOR THE STUDY OF MAMMAL POPULATIONS

By W. Frank Blair

Field investigations of mammalian populations by live trapping and marking methods involve the development of numerous new techniques. During four years of field studies of this type, the author has made certain general observations and developed various techniques that should be of aid to other investigators undertaking such studies. The methods herein described apply particularly to the study of small rodents, but many of them are directly applicable to larger forms. The investigations in which these techniques were developed involved the trapping of selected areas over several months of time. The principal objectives of these studies were to determine the size of individual home ranges and to learn the population density per unit area at various seasons of the year.

Additional information on live trapping techniques is available in a few publications that deal entirely or in part with such investigations. Included in these are the reports of Allen (1938, 1939a, and 1939b), Blair (1940a, b, c, and d), Burt (1940), Chitty (1937 and 1938), Dalke and Sime (1938), and Hamilton (1937 and 1939).

SELECTION OF HABITAT

In selecting an area to be trapped, one should, as a general rule, confine his attention to a single ecological association and to a relatively uniform area of that association. An ecological association, as defined here, includes all of the plants and animals occurring together in a relatively stable environment. Any given species that occurs in two or more ecological associations is apt to behave differently in each. For example, in southern Michigan

there is evidence that individuals of the wood mouse range more widely in the blue-grass than in the oak-hickory association (Blair, 1940d). Even in somewhat dissimilar parts of a single association there may be some difference in activity. The meadow vole tends to range more widely in areas of sparse than in areas of heavy grass cover (Hamilton, 1937, and Blair, 1940b). If more than one habitat type is included in the trapping area the results from each type should be evaluated separately.

When choosing a trapping site, one may pick a plot in a large, relatively uniform area of a single association type. Or one may select a relatively isolated area of the association to be studied. A woodlot surrounded by grassland would be virtually an island in so far as some semi-arboreal species of mammals are concerned. It should be kept in mind, however, that a given species sometimes behaves differently in a small island of an ecological association than it would in an extensive tract of the same association. Moreover, considerable trapping in associations assumed to be barriers must be done before one may be certain that they actually are barriers.

SIZE OF PLOTS; SPACING OF TRAPS

The size of the plot to be trapped is not vitally important if the area of association to be studied is surrounded by another association that is a more or less complete barrier to the species under investigation. Where no barrier to the species being studied surrounds the trapping plot, the size of the plot becomes extremely important. As a general rule, the plot should be from 10 to 20 times the expected size of the average home range of the species. Even then, an enlargement of the plot might be necessary if the first trapping records indicated a larger home range than was expected. As a rule, therefore, a plot of less than five acres would be too small for an accurate determination of the home range size or population density of most small mammals, unless the plot were surrounded by barriers. On a smaller plot, so many animals would have home ranges extending beyond the limits of the traps that they could not be included in any calculation of home range size. Likewise, some allowance would have to be made for them in any calculation of population per unit area. Therefore, the larger the plot the more numerous and reliable will be the trapping data. There is a limit, of course, to the size of the plot that one person can handle. As a rule one person would have difficulty in running a plot of more than 15 acres on which more than 100 animals a night were regularly caught.

The distances that the traps are spaced depend on local conditions and on the species of mammals to be studied. In the blue-grass association of southern Michigan a distance of 60 feet between traps that were in lines 60 feet apart was satisfactory. In the mesquite association in New Mexico the traps were set an average of about 45 feet apart in lines that likewise were 45 feet apart. Such close spacing proved unnecessary because of the large home ranges, so the traps were spaced approximately 45 feet apart in

lines that were 90 feet apart. By making this change it was possible to nearly double the size of the area being trapped without increasing the number of traps and without greatly increasing the amount of walking necessary. In the oak-hickory association in southern Michigan Burt (1940: 12) found that a distance of 45 feet between traps was satisfactory for the wood mouse.

To set the traps in grid pattern is desirable whenever this is feasible, as it simplifies the calculations of home range size and insures even distribution of traps over the plot. In some instances, however, the traps must be set at irregular intervals. In the mesquite association of southern New Mexico it was necessary to set the traps near mesquite bushes to protect them from trampling by cattle and from the sun's rays. Likewise, it was known that most of the small mammals frequent the vicinity of the mesquites, crossing the intervening barren ground only in going from one mesquite to another. Before the traps were set out stakes were driven 45 feet apart in several parallel lines that ran the entire length of the plots. In putting out traps the operator followed the lines as nearly as possible, with one trap usually being put out for each stake but at the nearest mesquite bush. The positions of the traps on the plot were located by measuring from the nearest stake.

BAITS AND NESTING MATERIAL

Sunflower seed has proved the most satisfactory of several baits for small mammals, but several other seeds have been effective. Sunflower seed has been highly attractive to *Peromyscus*, *Zapus*, *Microtus*, *Synaptomys*, *Perognathus*, *Dipodomys*, *Onychomys*, *Reithrodontomys*, *Sigmodon*, *Neotoma*, and *Citellus*. With live traps it has the advantage of interfering less with the working of the trap door and treadle than do smaller seeds. Wheat, oats, millet, canary seed, hemp, and cracked corn are effective baits, either singly or in various combinations, but they have the disadvantage of occasionally jamming the treadle. Whole seeds have a great advantage over pulverized grain such as rolled oats or corn meal, particularly where there is frequent rain. Wet rolled oats or corn meal is very messy and difficult to remove from the traps, whereas wet seeds soon dry out and, in fact, usually do not even need to be replaced.

A small wad of cotton (about 6 grams) should be placed in each trap to provide nesting material for any animal that may be caught. The cotton should be wadded rather loosely. If it is tightly wadded some animals (*Perognathus* and the young of several other forms) seem unable to tear it apart to make a nest. The cotton should be replaced if it becomes dampened by rain, but it can be dried and used again.

TRAPPING ROUTINE

The traps should be visited twice daily in most investigations of nocturnal mammals. They should be set sufficiently late in the afternoon that no individuals will get in them and be killed by the heat of the sun. In the

morning, the traps should be run as soon after daylight as possible. At this time, all traps should be set off. This may be done quickly and easily by turning them bottom side up. It is absolutely essential, under most trapping conditions, to leave the traps unset during the day. Where an area is trapped for several consecutive nights some individuals invariably will get in traps that are left set during the day and be killed by the heat of the sun. In investigations of crepuscular forms the traps should be set as early in the afternoon and run as late in the morning as is possible without having the animals die from the heat.

In extremely cold weather either one of two trapping routines should be followed to prevent death of the captives from cold. The traps may be set late in the afternoon; then run three or four hours after dark, at which time all traps should be set off until the following afternoon. This method has the obvious disadvantage of getting a smaller number of the animals that are active on the plot than would a full night of trapping. A more satisfactory way is to run the traps three or four hours after dark, at which time all of the traps that contain animals are set off for the remainder of the night. Then the traps should be revisited in the morning, at which time the remaining traps should be set off until afternoon. With this method no individual has to remain in the same trap throughout the night. Many of the animals caught during the first half of the night may be taken in other traps in the last half, but their stay in the traps will have been interrupted by a period of activity between the first and second periods of captivity.

In home range studies, it is important that each individual be caught at as many points in its home range as possible. Some individuals, however, tend to be caught in the same trap night after night as long as that trap remains set. This generally happens when the trap is set near the home site of the animal. A simple method of reducing the amount of this repetition may be used. Each trap that has the same animal in it on two consecutive nights is left unset on the third, thus permitting the animal to be caught in some other trap. Another method of insuring that each animal will be caught at as many points in its home range as possible is to set two plots side by side. Then they will be trapped during alternate weeks. Animals living along the border between them will be caught in one plot one week and in the other the next. This method proved satisfactory in the mesquite association of New Mexico. The plots should be longer than they are broad to give a long line of contact between them. The idea may be carried even further by having several long narrow plots lying side by side and trapping alternate plots during alternate weeks. Or alternate lines in a single plot may be trapped during alternate nights. The important thing is to trap each animal in as nearly as possible the entirety of its *normal* home range. With the methods outlined above the chances are reduced that an animal will continue to get into the traps nearest its home site, as long as trapping is done, without ever reaching the periphery of its normal range.

REMOVING SMALL MAMMALS FROM THE TRAPS

Various methods of taking captive small mammals from traps have been used. Methods that are satisfactory for some species will not work with others. Twelve-inch forceps, tipped with rubber tubing, are excellent for removing mice of the genera *Peromyscus* and *Onychomys*. The forceps are used to grasp the tail, after which the mouse may be secured firmly by grasping the nape between the thumb and fore-finger. Mice should not be caught by the hind legs, as a sudden twist sometimes will break them. Forceps should be used with caution on animals whose tail breaks easily, such as kangaroo rats, pocket mice, and jumping mice. With kangaroo rats, pocket mice, and lemming voles, one may open the door of the trap, shake it to stimulate the animal and as it emerges from the trap catch it with a hand held near the door. With practice, one soon becomes adept at this rapid way of removing the captives. This method is not recommended for species that are prone to bite. Animals that are not readily handled by one of the above methods may be shaken from the trap into a small cloth sack. Then they may be grasped through the cloth and removed from the sack. Caution should be used in opening trap doors where jumping mice or house mice are being trapped, as both forms are prone to leap from the trap and escape the instant the door is opened. This may be prevented by slipping the sack over the end of the trap before the door is opened.

METHODS OF MARKING

Each animal should be marked the first time it is caught, so it can be recognized each time it is subsequently taken. Many species of small mammals may be marked by punching holes at designated places in the ears and by clipping off certain toes. With this method one ear is used to show units; the other to show tens. Five basic loci are utilized on the margin of each ear. Thus, a punch in the front margin of the ear and near the head indicates *one*; a punch in the margin half-way between this and the tip of the ear indicates *two*. A punch in the tip indicates *three*, one midway of the back margin indicates *four*; one where the back margin joins the head is *five*. The one and two punches are combined for *six*; the two and three for *seven*; the three and four for *eight*; the four and five for *nine*. Exactly the same method is used on the other ear to show the tens. Using the ears alone one may mark 99 animals without repeating. If one front toe is cut off to indicate each hundred from one to eight hundred, it is possible to mark 899 individuals without repeating. Burt (1940: fig. 1) used essentially the same system, but he also punched a hole near the center of each ear, thereby giving many more possible combinations. I have found that mice frequently snag this center hole, thereby tearing the ear and making the number difficult or sometimes impossible to read. If more than 900 animals are to be marked it would be best, in most cases, to cut one toe off a hind foot, which would give an adequate

number of combinations for most investigations. The ear punching is done with a poultry punch; the toes are clipped with small scissors.

Some small mammals such as shrews, pocket mice, and ground squirrels have ears that are too small to be marked by the poultry punch method. Up to 109 pocket mice or ground squirrels may be numbered by toe clipping alone, using one front toe to indicate each unit, one back toe to indicate each ten. This may be done without clipping more than one front and one back toe on each animal (except for those ending in nine, in which case the first and eighth toe on the front would be clipped). Shrews, having one more toe on each front foot, offer more combinations. Toes that have been clipped occasionally become infected, but heal after a short time. I know of no case in which an animal died or appeared ill from the effects of toe clipping.

Numbered aluminum rings, analogous to bird bands, have been used by Chitty (1937: 42) for marking small mammals. There would be an advantage in using these if one were studying predation, as some of the bands could be recovered from owl pellets and mammal feces.

MORTALITY IN THE TRAPS

The death of very many individuals in the traps must be prevented if any long-term study of home ranges or population density is to be successful. It is virtually impossible to eliminate completely some mortality in the traps. It is possible, however, to reduce it to a negligible factor under reasonably satisfactory trapping conditions. Cold is the most serious of the factors causing death in the traps. Most small mammals will survive quite severe chilling once or twice, but repeated chilling frequently causes death. Nesting material is necessary, therefore, even in summer in most parts of the country, if the same individuals are to be trapped on several consecutive nights. Heat is much less important than cold as a mortality factor. Usually, only direct sunlight on the traps causes sufficient heat to produce death. In many ecological associations it is possible to place the traps where they will be shaded by vegetation. Where no shade is available it is necessary to run the traps and release the animals before the sun rises high enough to kill them.

Ants are a serious obstacle to live trapping of small mammals in the south during the warm months. Running the traps shortly after daylight, or before with the aid of a head-light, helps to prevent the destruction of captive animals by ants, as many species of ants apparently are largely diurnal in their activity. Local ant colonies may be controlled by a simple trapping method. A jar or can, baited with a mixture of molasses and water, is sunk flush with the surface of the ground and covered with coarse wire mesh to keep out small mammals. The ants are attracted to the molasses and fall into the jars and are drowned.

Fighting among individuals of the same or different species when multiple-catch traps are used occasionally causes the death of one or more individuals.

This makes undesirable the use of such traps in places where animals that tend to fight, such as meadow voles, shrews, pocket mice, and kangaroo rats, are apt to be taken. Occasionally predators will disturb the traps. At various times my traps have been molested by weasels, dogs, coyotes, red foxes, and rattlesnakes, and on rare occasions these have destroyed captive animals. Another rare cause of death is injury by the trap mechanism. On occasion deer mice and shrews have been caught beneath the falling door and have been injured or killed.

TRAPPING RECORDS

Trapping records are best kept on looseleaf note paper, which is carried in an aluminum cover just small enough to fit the hip pocket. The cover that I use takes sheets that have the dimensions of $8\frac{1}{2}$ by $4\frac{3}{4}$ inches. Cross-ruled paper is used because it is readily ruled into columns. Two types of records are kept. In one file (fig. 1) is entered each individual at the time it is marked. The age class, sex, species, and the number given to each animal are recorded here. Likewise, the number of the plot and trap in which the animal first was caught and the date of first capture are recorded. One column is provided for later recording the date of death if it is known. Thus, in figure 1, an adult male *Dipodomys ordii* (abbreviated to D.O. to save time and space) was the first mammal caught and was given the number, one. This animal was first caught in plot 1, trap 18, on March 1, 1940. It later was killed by ants on June 2, 1940. This file is carried permanently in the field note book, where it is available for reference and for the addition of newly marked animals. The other record (fig. 2) is kept for each trapping period (usually several days), and at the end of that time it is removed from the field note book. On this record sheet, there are separate columns for recording the age class, sex, field number, species, and breeding condition of each animal. In addition, there is a column for each day of trapping. In this last, is placed each day the number of the trap in which each animal was caught. Under "breeding condition" is recorded the approximate size of the testes of the males. For the females, is recorded the condition of the mammae and external genitalia and whether or not each female appears to be pregnant. This record of breeding activity is important in later evaluating the home range and population data. The method of keeping the trapping period record is illustrated in figure 2. The adult male *Dipodomys ordii* bearing the number, one, was sexually active as indicated by its large testes. This animal was caught in trap number 18 on March 1, in trap 20 on March 2, in trap 32 on March 3, etc.

CALCULATING AREA OF HOME RANGES

A satisfactory method of calculating the size of individual home ranges from trapping data already has been described (Blair, 1940b: 151 and fig. 1). This,

like any other method using trap data, does not show the exact size and shape of the home range. Nevertheless, I do believe that it approximates them. It has the great advantage of lending itself readily to statistical treatment.

Age	Sex	No.	Sp.	Plot - Trap	Date Marked	Date Dead
Ad.	♂	1	D.o.	1 - 18	3/1/40	6/2/40 (ants)
"	♀	2	D.m.	1 - 42	3/1/40	
"	♂	3	b.	2 - 312	3/1/40	
Im.	♀	4	t.	1 - 53	3/1/40	
Ad.	♀	5	b.	1 - 14	3/2/40	
"	♀	6	D.o.	2 - 390	3/2/40	
Im.	♂	7	D.o.	1 - 10	3/3/40	
Ad.	♂	8	D.m.	1 - 4	3/4/40	

FIG. 1. Diagram illustrating the permanent marking file. This is a record of all of the animals marked during the course of a field investigation. It is kept permanently in the field note book, and is added to as new animals are marked.

Plot 1 — March

Age	Sex	No.	Sp.	Breeding	1	2	3	4	5	6	7
Ad.	♂	1	D.o.	large	18	20	32	67	102	104	18
"	♀	2	D.m.	pregnant	42	42	43	86	42	91	35
Im.	♀	4	t.	no	53	5		12	49	86	
Ad.	♀	5	b.	dry		14	15	17	34		12
Im.	♂	7	D.o.	medium			10	10	11	19	10
Ad.	♂	8	D.m.	small				4			
"	♀	9	b.	suckling				5	16	23	48
"	♂	10	D.o.	large					8	100	16

FIG. 2. Diagram illustrating record for one trapping period. This records the breeding condition of each animal during that period and the number of the trap in which it was caught on each night. This record is removed from the field note book at the end of each trapping period.

The size and area of the home range should be calculated for a relatively short period. One month has proved a satisfactory unit for this purpose. If larger units are used—seasons or years—movements from one home range to another or a shifting of the range may introduce a high degree of error. In

calculating the average size of the home range of an animal, those individuals whose ranges are near the borders of the plot should be excluded as the ranges of most of them probably extend beyond the trapping limits. Also, those individuals on the plots that have been caught only a few times should be ignored.

CALCULATING POPULATIONS PER UNIT AREA

The number of individuals of any species on a given area, according to my observations, is continually changing. Some individuals move into the area; others move away or perish. Therefore, any calculation of the population on the area should be made over a relatively short period of time. On the other hand, the area must be trapped long enough to insure that most of the residents have been recorded. The optimum trapping period doubtless varies under various ecological conditions. The period of one week has proved a satisfactory unit in most of my studies of populations. A shorter trapping period cannot always be relied upon to catch all of the resident animals. Most small mammals are less active under certain weather conditions than under others. Thus only a few nights of trapping under unfavorable weather conditions would be unlikely to take all of the resident animals.

In calculating population density per unit area some allowance must be made for animals taken near the borders of the plot whose home ranges extend beyond the trapping area. This may be done by adding, on each side on which there is no barrier to the species, one-half the width of the average home range. Some distinction also should be made between animals that are resident on the plot and those that are taken there as transients.

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THE SHOULDER ANATOMY OF THE ARMADILLO

BY SAMUEL S. MILES

Five adult armadillos of the Texas variety, *Dasypus novemcinctus texanus*, were obtained alive in good condition, the shoulder region in three of which was completely dissected. The present study deals with the muscles acting upon the scapula, clavicle and humerus, and the nerves innervating these muscles. Description of the brachial plexus and of the muscles of the brachium is included.

The classification of muscles used is that proposed by A. B. Howell. Innervation is the criterion of identification, although the muscles with common innervations are distinguished by their other morphological characteristics.

OSTEOLOGY

Despite the plasticity of movement in the forelimb of *Dasypus* the general "design" and pattern seems adapted to one particular type of action, digging. The necessity for powerful retraction of the manus is reflected in the musculature and bony structure of the whole pectoral girdle.

The paper-thin scapula, reinforced by a bar-like thickening of the bone along the inferior and vertebral borders and by the spine, is a framework able to withstand great antero-posterior forces. The long slender falciform inferior border allows a remarkably extensive origin of the powerful scapular head of the triceps, and of the serratus, permitting tremendous leverage in this plane. In the thickened posterior tip of this border the fine bony trabeculations can be seen in the X-ray ranged in compressional and tensile lines to meet such forces.

The scapulohumeral articulation is largely in this plane of movement, the glenoid cavity being an oval surface allowing almost 90 degrees of extension and flexion, but less than 45 degrees of rotation or abduction. The humerus is short and thick, with broad surfaces for muscular attachments. The deltoid crest extends almost halfway down the shaft. The more cylindrical upper half of the shaft flattens toward the broad lower half. A large entepicondylar foramen occurs above the well developed medial epicondyle.

On the posterolateral border a wide flange is developed for the origin of the humeral head of the triceps.

The radius and ulna are bound tightly together by the interosseous membrane, allowing very little if any pronation or supination. The olecranon process is remarkably extended to more than one-third the entire length of the ulna and consists of a superior (compressional) bar and an inferior (tensile) bar with a thin bony partition between. The trabeculations of these bars extend to the olecranon tip and are directed to withstand the great pull of the triceps.

The clavicle is long, gently curved, and of uniform thickness. It articulates by a ligament about 1.5 cm long and 0.3 cm in diameter, in which are found the three episternal ossicles. This ligament inserts upon the deep surface of a flat epiphysis-like structure (cartilaginous in a young specimen, calcified in an older one) extending from the anterior aspect of the presternum. The anterior border of this episternal bone has a shallow notch, and may correspond to the bifid element mentioned by Luschka (1859), which he considered an incipient separation into the two elements found in *Dasypus sexcinctus*. Gegenbauer's (1865) view apparently coincides with these. Parker's (1868) figure of the shoulder girdle of a "ripe embryo" of *Tatusia peba* shows this episternal prominence, but there is no discussion of its homology. He also figured two episternal ossicles which he considered omosternal and precoracoid elements.

The shoulder girdle was macerated in only one of my specimens and in this, an old male, three episternal ossicles were found. Lying deep in the sternoclavicular ligament, they were not suspected until an X-ray of the clavicle was taken. The largest lay nearest the clavicular end, the smallest near the sternum. The presternum is a broad flat bone articulating with the first and second ribs, the mesosternum and the clavicles.

BRACHIAL PLEXUS

The brachial plexus of *Dasypus* is fairly close in pattern to the fundamental mammalian plan. It arises from the last 4 cervical and first thoracic nerves (C_5 to T_1), its axis passing through C_7. Three cords are formed in the usual manner by the union of C_5 and C_6, by C_7, and by the union of C_8 and T_1. The plexus should be considered as slightly more prefixed than that of man, however, since the element from C_5 is massive and forms the greater part of the axillary nerve, while that from T_1 is relatively insignificant, contributing a few fibers to the anterior thoracic nerve (to the panniculus) and to the ulnar nerve. The splitting of the plexus into dorsal and ventral components occurs close to the cervical vertebrae. This is possibly due to the quite distinct anatomical situation and functional specialization of the flexor and extensor muscles. As might be expected, the ventral division of the plexus is of smaller mass than the dorsal, reflecting the weaker development of the

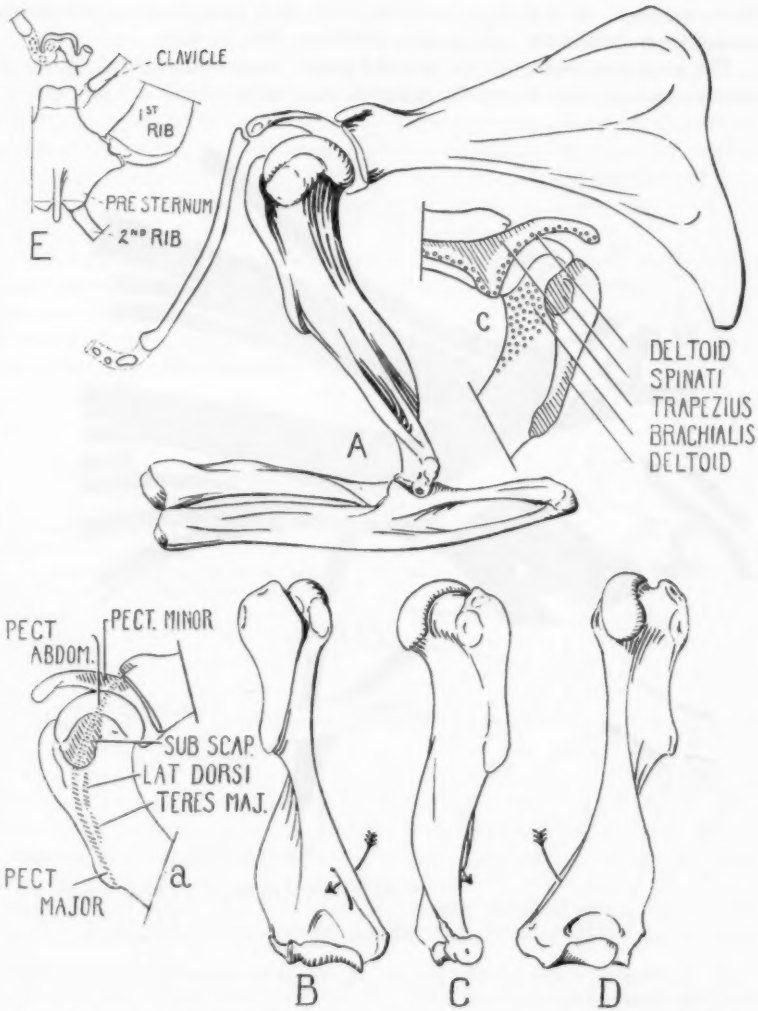

FIG. 1. Bones of shoulder girdle. A. Medial view. a. Showing muscular attachments. B. Humerus—anterior view. C. Humerus—lateral view. c. Showing muscular attachments. D. Humerus—posterior view. E. Attachment of clavicle and ribs with presternum, ventral view (smaller inset—dorsal view showing position of sternoclavicular ligaments and episternal ossicles). In a and c the origins of muscles are shown by circles and the insertions by hatching.

flexor muscles. It is perhaps odd that with such specialization, the plexus maintains a "primitive" diffuse plan similar to that of man.

The gross morphology of the brachial plexus is shown in figure 1, the nerve branches having been forcefully separated proximally to only a minor extent.

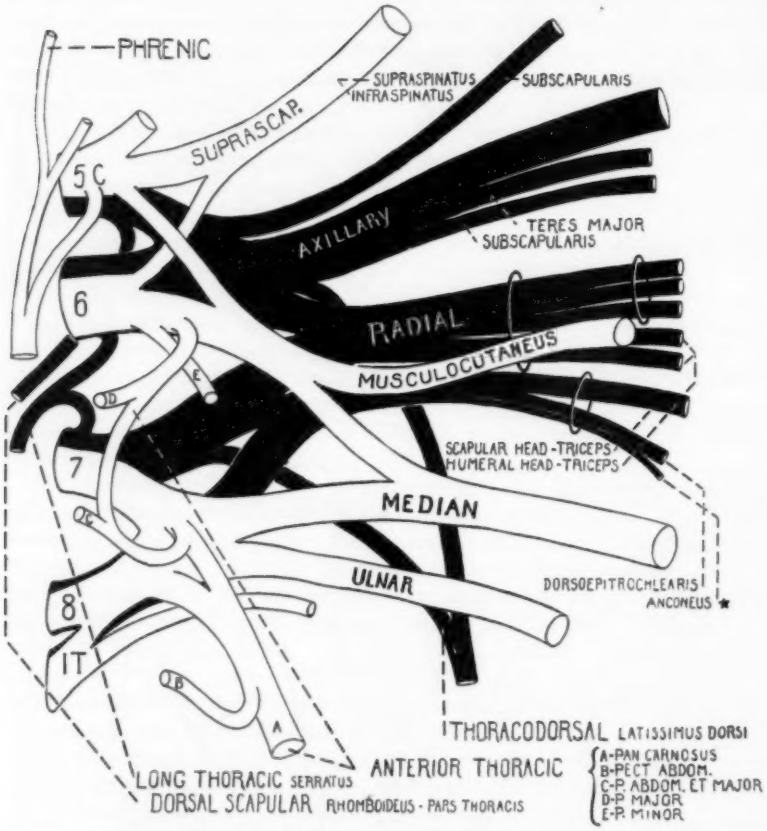

FIG. 2. Diagram of left brachial plexus. M. triceps anconeus receives motor fibers from both ulnar and radial nerves.

The course of the fiber bundles within the anastomoses of the plexus was studied in two cleared preparations from the two sides of one animal by the method described below.

The plexus was dissected out grossly and the main nerves identified. It was then completely freed from the surrounding tissues, cut proximally and

peripherally, and placed in a 1 per cent acid solution of pepsin between 30–40°C. for two hours and then left in the solution at room temperature overnight. The connective tissue binding the nerves in the plexus was thus largely digested and what remained of the much softened tissues was removed for the most part with considerable ease under the low power dissecting microscope. The plexus was then washed and fixed in 10 per cent formalin, washed again, dehydrated by passage through 50 per cent to absolute alcohol, and cleared in oil of wintergreen (methyl salicylate), and finally mounted in balsam on a 2 by 3 inch glass slide.

The results obtained were satisfactory, but it was felt that the preparations could have been improved by removal of the lower cervical spinal cord with the nerve roots intact, by accurate regulation of the acidity to a pH between 2 and 3, and by use of a water bath accurately maintained at body temperature. An active preparation of chemically pure pepsin is recommended,

TABLE 1.—*Main nerve branches*

VENTRAL	ROOTS OF PLEXUS					DORSAL	ROOTS OF PLEXUS				
	5	6	7	8	1		5	6	7	8	1
Suprascapular	+++	++				Subscapular	++++				
Musculocutaneous	++++	?	+			Axillary	+++	++			
						Radial	+	++	+++	++	
Median	?	++	++	+		Thoracodorsal	+	++	++		
Ulnar			+	+++	+	Long thoracic		++	++		
Anterior Thoracic		++	++	++	+	Dorsal scapular	+++				

although in these preparations a crude product was used which is produced for therapeutic use.

By examination of these specimens with the microscope the root origins of the main branches of the plexus were confirmed, except for the long thoracic and dorsal scapular nerves, which had been torn and distorted by the dissection. Several finer components of the suprascapular, axillary, radial, and musculocutaneous nerves maintained their identity not only into the divisions of the plexus but even in some cases into the roots themselves. Their respective innervation of separate muscles was not determined, but this seems a likely possibility.

The suprascapular nerve proved to be distinctly ventral in origin, while the subscapular nerves, arising from a common nerve bundle in C_5, were definitely dorsal. At first, on gross dissection, the proximity of the superior branch of the subscapular to the suprascapular nerve suggested that they might have a common origin. Likewise, as the superior part of m. subscapularis was fused with the adjacent part of m. supraspinatus, it was thought that these muscles might have a common phylogeny. Such was not indicated.

The musculocutaneous nerve, arising largely from C_5, was found to receive a fine contribution from C_7, which ran with it but maintained its identity. No contribution from C_6 was seen, although at one point in their common path the musculocutaneous and median nerves lose their absolute separation, so this possibility exists.

The brachial plexus of *Dasypus novemcinctus* differs from that of the hairy armadillo, *Euphractus* (*Dasypus*) *villosus* (Harris), in that there is no branch from the 4th cervical root. Other minor differences are found.

MUSCULATURE

M. platysma is broad and fan-shaped with origin over the cheek. It spreads posteriorally to m. panniculus, into which its fibers insert, forming with the latter an anatomical and functional unit. There is a thin sheet of fibers from the main muscle to the skin beneath the neck (not figured). Innervation: n. VII. Many nerve fibers pass from C_3 and C_4 to penetrate the muscle, but these are probably sensory to the skin.

M. trapezius is divided into two parts. The superficial part is fan-shaped and originates from the mid-line in the cervical and anterior thoracic regions and from the dorsal portion of the shell. The fibers converge to the acromion, the scapular spine and the aponeurosis of the scapular head of m. deltoideus. The most anterior portion forms a separate superficial slip with fibers overlapping the posterior portion. The deep part has its origin by aponeurosis from the thoracic spines and inserts by a tendon curving around the acromiovertebral angle of the scapula to the deltoid aponeurosis close to the middle third of the spine. Innervation: n. XI, which passes through the mastoid end of m. sternocleidomastoideus, over the coracoid border of the scapula close to the glenoid angle and posteriorly along the spine. It passes between the supraspinatus and the overlying trapezius, to which it sends fibers. It then passes under the tendon of insertion of the deep part of m. trapezius, entering the deep surface of this part.

It is of interest that the trapezius has no origin on the skull, unless the lateral m. cleidomastoideus be considered as part of this muscle. It should also be noted that m. trapezius was not found to have anatomical union with the panniculus, as has been described.

M. sternomastoideus is long and fusiform from manubrium to mastoid, where it inserts with the medial m. cleidomastoideus.

M. cleidomastoideus forms two bands from the medial half of the clavicle to the mastoidal region. The more medial is a slip from m. sternomastoideus; the lateral originates more posteriorly on the fascia of the neck close to the midline and lambdoidal ridge. Innervation: n. XI and C_2.

The dorsoscapular or suprazonal group is represented by mm. serratus anterior and rhomboidei.

M. serratus anterior originates from the lateral aspect of the thorax and

the transverse processes of the last two or three cervical vertebrae. It extends caudally to the 6th rib, and spreads dorsally and cranially as a thin sheet to insert along the medial aspect of the vertebral border of the scapula. The cervical portion is thickest. The posterior portion, from the 4th to 6th ribs, is fan-shaped; its fibers separate from the anterior part, converging on the medial aspect of the coracovertebral angle of the scapula. Innervation: long thoracic nerve (C_5, C_6, C_7).

No muscle corresponding to m. levator scapulae is found in Dasypus.

M. rhomboideus, pars thoracic is fan-shaped, arising from an extensive lateral aponeurosis shared by the origin of the "thoracic triceps". Insertion is upon the ventral third of the vertebral border of the scapular and the adjoining medial surface. This part of the rhomboideus acts directly in antagonism to the similarly shaped posterior portion of m. serratus. Innervation: dorsal scapular nerve (C_5). This muscle, although closely related anatomically to the posterior part of the serratus, is considered as part of the rhomboid group because of its position and innervation by C_5. This innervation, the dorsoscapular nerve, runs close to the long thoracic nerve from C_6 to C_7, penetrating the cervical part of the serratus and running parallel to the long thoracic nerve.

Pars capitis is a heavier muscle that extends from its origin along the lambdoidal crest and midline to insert on the coracovertebral angle of the scapula. Innervation: C_3. This muscle is also considered as part of m. rhomboideus, although its innervation, position, and structure superficially varies more from the pars thoracis than the pars thoracis does from the serratus. This is so considered because of its origin from the lambdoidal crest, whereas only that part of the present complex arising from the anterior cervical transverse processes, or basioccipital (not occurring in *Dasypus*), is considered as being a m. levator scapulae.

The dorsal shoulder derivatives consist of the thoracodorsal and axillary matrices. The thoracodorsal matrix is represented by mm. latissimus dorsi, teres major, and subscapularis.

M. latissimus dorsi originates by slips from the 5th to 8th costochondral junctions, and inserts in m. pectoralis abdominis and in the bicipital groove of the humerus, its insertion straddling the coracoid head of the biceps brachii. The upper border of the latissimus dorsi is bound to the posterior axillary border of the scapula by a strong fascial band passing over m. teres major (see m. dorsoepitrochlearis). Innervation: thoracodorsal nerve (C_5, C_8, C_7).

M. teres major originates from the vertebral third of the axillary border of the scapula and inserts in the bicipital groove of the humerus just distal to m. latissimus dorsi. Innervation: subscapular nerve (C_5, C_6).

M. subscapularis is divided into three parts, originating from the fossa subscapularis and inserting by a common thick tendon upon the lesser tuberosity of the humerus. The superior part is a thick muscle the belly of

which is inseparable from the upper border of m. supraspinatus. Some of its fibers insert upon the aponeurotic sheath of the middle part. The latter is a

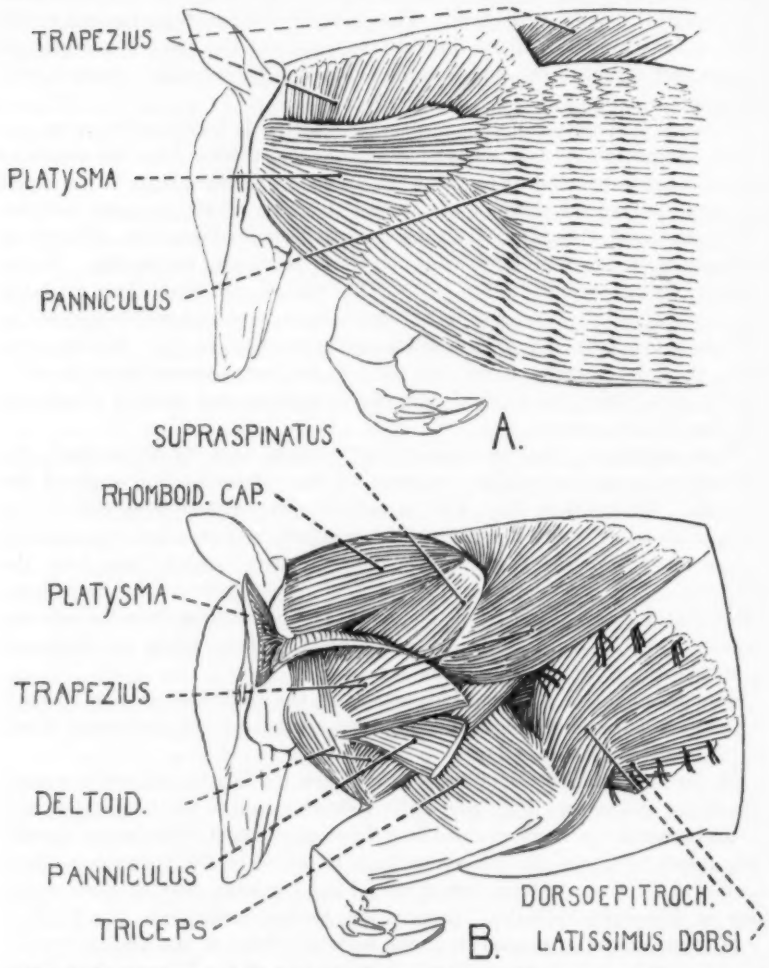

FIG. 3. *Dasypus novemcinctus*. A. Shell removed uncovering m. panniculus carnosus. B. M. panniculus removed.

broad thin pinnate muscle; the inferior part is small and intimately connected with the middle part. Innervation: subscapular nerves (C_5). The nerve to the superior part separates from the axillary nerve close to the union of the

roots from C_5 and C_6, but has fibers from C_5 alone. The nerves to the middle and inferior parts leave the axillary nerve more distally along with those

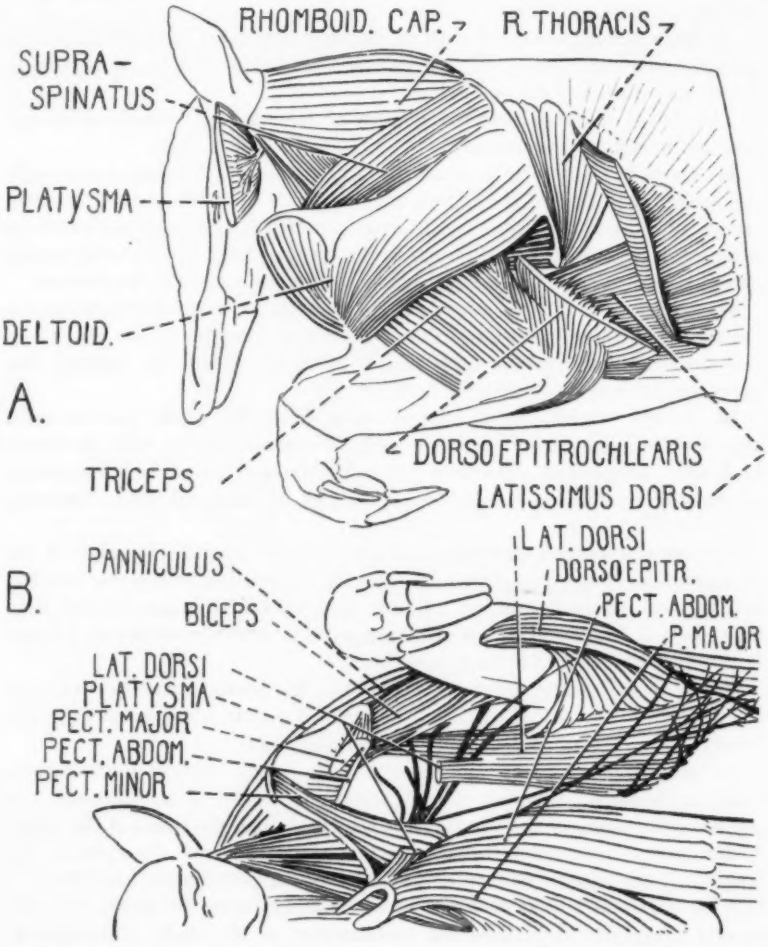

FIG. 4. *Dasypus novemcinctus*. A. M. trapezius removed. B. Ventral view; pectoral muscles cut and reflected. The head of m. latissimus dorsi to m. pectoralis abdominis is cut.

to the teres major. The innervation of the superior and the other two parts is quite separate and distinct peripherally.

The axillary matrix consists of mm. deltoideus and teres minor.

M. deltoideus is remarkable for the broad, flat portion from the lower vertebral border and spine of the scapula to the deltoid ridge. The acromial and clavicular portions have their insertion with this band and are not noteworthy.

M. teres minor is so fused with m. infraspinatus as to be indistinguishable except by its innervation. It will be discussed below with m. infraspinatus. Innervation: axillary nerve (C_5, C_6).

The dorsal elbow derivatives consists of mm. triceps brachii, dorso-epitrochlearis and triceps anconei.

M. dorso-epitrochlearis is unusually well developed, forming a seemingly unique thoracic head of the triceps which extends from the body of m. latissimus, with which its fibers are intimately mingled, and from the extensive dorsolateral aponeurosis. It inserts in the scapular head of m. triceps brachii close to the olecranon and upon the medial extensor surface of the forearm.

M. triceps brachii, caput scapularis is a very thick powerful muscle extending from the anterior three-fourths of the axillary border of the scapula to the olecranon process. A deep fissure partially divides the muscle into anteromedial and posterolateral portions.

M. triceps brachii, caput humeri arises from the whole posteromedial aspect of the humerus and inserts upon the olecranon process with the scapular head. A superficial slip arising just below the insertion of the infraspinatus passes over the brachialis to the main body of the humeral head. Innervation: radial nerve.

M. triceps anconeus (internus) extends from the medial epicondyle to the medial border of the olecranon. The double innervation, which was checked by electrical stimulation in two animals, suggests that this muscle may have been formed by fusion of epitrochleo-anconeus and the anconeus triceps. Innervation: radial and ulnar nerves.

The ventral shoulder derivatives consist of the pectoral, anterior coracoid and posterior coracoid matrices. The pectoral matrix is represented by the panniculus and mm. pectoralis minor and abdominis.

M. panniculus carnosus extends as a thin, broad, superficial sheet from thigh to shoulder. Its origin is from the caudal border of m. platysma. It inserts on the edges of the bands of the shell and upon the fascia of the thigh. A slip extends posteriorly from fascia over the deltoid and the spine of the scapula to the medial surface of the belly of m. panniculus. In *Dasypus* there is a loss of the usual humeral attachment, since the panniculus has become singularly specialized for mobilization of the shell. Innervation: posterior part of anterior thoracic nerve (C_7, C_8, T_1). Nerve fibers also seem to enter the muscle from the intercostal nerves (T_2 to T_6). There are typically two branches from each nerve, a lateral and an anterior division. The former group passes between mm. trapezius and dorso-epitrochlearis to enter the dorsal part of m. panniculus. The latter group passes medial to mm. latis-

simus dorsi and dorso-epitrochlearis to enter the ventral part of the muscle. I have shown elsewhere that in all probability these are of sensory nature.

M. pectoralis minor extends from the flattened sternal end of the 1st rib to the inferior aspect of the acromion. The body of the muscle passes along the distal two-thirds of the clavicle, but its fibers do not insert upon it. Innervation: C_8 (C_8?). This nerve arises close to the cranial portion of the anterior thoracic loop.

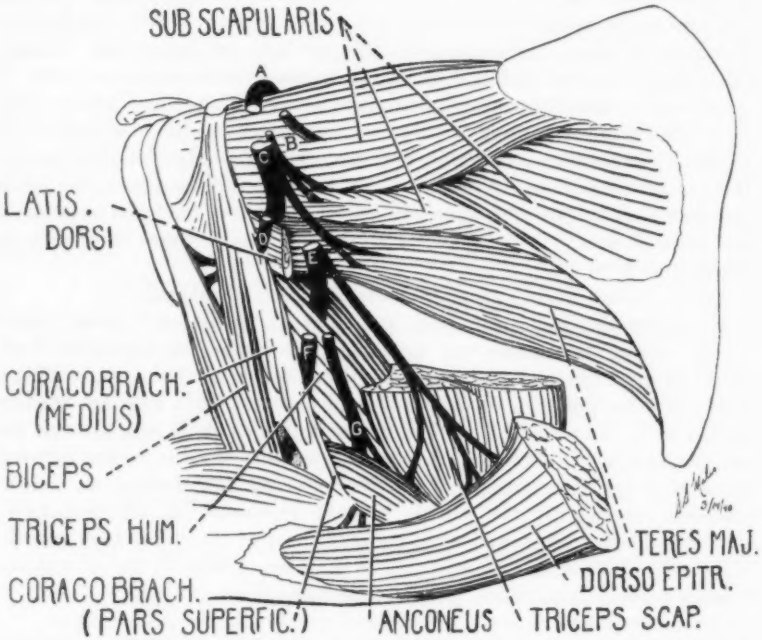

FIG. 5. Right brachium and scapula, medial view. A. N. suprascapularis. B. N. subscapularis. C. N. axillaris. D. N. musculocutaneous. E. N. radialis. F. N. medianus. G. N. ulnaris.

M. pectoralis abdominis arises from the cranial border of m. rectus abdominis and extends to the medial edge of the greater tuberosity, the shoulder capsule, and the coracoid process. The fibers pass medial and deep to those of m. pectoralis major. The medial head of m. latissimus dorsi inserts in m. pectoralis abdominis near its insertion upon the capsule. Innervation: anterior thoracic nerve, a part by the prominent branch to m. panniculus carnosus, and a part by the anterior thoracic loop (C_7, C_8).

The anterior coracoid matrix is represented by mm. pectoralis major, supra- and infraspinatus.

M. pectoralis major arises from the midline for the length of the sternum and inserts upon the medial inferior edge of the greater tuberosity with m. pectoralis abdominis as described above. The edges of these muscles are adjacent but can be easily separated by blunt dissection. Innervation: anterior thoracic nerve (C_6, C_7, C_8?).

Mm. supraspinatus et infraspinatus have their origins respectively from the supra- and infraspinous fossae. They are both well developed and extend from the fossae and the spine of the scapula to insert by a common tendon upon the whole superior border of the greater tuberosity. As described above, the fibers of mm. supraspinatus et subscapularis are inseparably mingled along their superior borders. M. infraspinatus is intimately fused with m. teres minor so that the two are indistinguishable except by innervation. This fused muscle inserts not only with m. supraspinatus but has a separate head to the greater tuberosity inferior and deep to the insertion of that muscle. Innervation: suprascapular nerve (C_5, C_6). The axillary nerve also sends extensive fibers to both the superficial and deep heads of the fused teres minor and infraspinatus. It is logical, however, to consider these fibers only as innervation to m. teres minor.

The posterior coracoid matrix consists of m. coracobrachialis.

M. coracobrachialis arises from the coracoid process and passes superficially over m. teres major and the humeral insertion of m. latissimus dorsi. It inserts upon the medial aspect of the distal half of the humerus, sending a thin tendinous insertion to the medial epicondyle. Both slips are entirely superficial to the median nerve and brachial artery, which pass through the large entepicondylar foramen. There is a fine group of veins passing between the slender tendinous insertion and the humerus. There is no m. coracobrachialis profundus; the muscle present represents in all probability coracobrachialis medius and (the tendinous part to the epicondyle) superficialis. The belly of the muscle is pierced in its upper third by the musculocutaneous nerve. Innervation: musculocutaneous nerve (C_5, C_6).

The ventral elbow derivatives consist of mm. brachialis and biceps.

M. brachialis originates from the posterolateral aspect of the upper end of the humerus posterior to the greater tuberosity. It curves laterally around the shaft of the humerus to insert upon the ulna just distal to the insertion of m. biceps brachii. There is no division into lateral and medial heads. Innervation: musculocutaneous nerve (C_5, C_6), which pierces m. coracobrachialis, deep to m. biceps brachii, and courses around the anterior aspect of the shaft of the humerus. There are also several fibers from the radial nerve to m. brachialis, as the nerve passes superficially to the fascia of the forearm.

M. biceps brachii is comparatively poorly developed. It originates from the superior lip of the glenoid fossa and the coracoid process and inserts upon the shaft of the ulna medial to and just below the head of the radius. A poorly developed lacertus fibrosus is present. The coracoid head is inti-

mately associated with m. coracobrachialis, its tendon and fibers running in close union with this muscle. The long and short heads join at about the level of the junction of the middle and upper thirds of the humerus. Innervation: musculocutaneous nerve (C_5, C_6).

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ECOLOGIC RELATIONSHIPS OF FOUR SMALL MAMMALS IN WESTERN WASHINGTON

By Walter W. Dalquest

This account is based upon four years observations of the small mammal population in a small, dark, damp ravine, west of the Cascade mountains in the state of Washington. Such ravines are a typical feature of the humid transition zone of the state and are found wherever a small stream of water flows through dense coniferous forest. The ravines contain a flora and fauna that is both quantitatively and qualitatively different from that of the coniferous forests.

The ravine studied is about five acres and situated on the University of Washington Campus at Seattle. It is bordered on three sides by dry hillsides covered with western red cedar, western hemlock, and douglas fir. The eastern, or downstream, end of the ravine was at one time open to Lake Washington and its large bordering marshes, but a railroad embankment, railroad tracks, and a paved highway now close this end. At present the ravine is comparatively isolated.

The flora of the ravine consists of broad leaf maple, red cedar, and alder. The underbrush is extremely dense and consists of salmonberry, red elderberry, and devils club bushes. A few thimbleberry, hazel, red huckleberry and blackberry bushes grow on raised spots in the ravine. The ground is covered with grasses of several species, sword ferns, horsetail, and skunk cabbage.

The floor of the ravine is cris-crossed with rotting fir, hemlock, and cedar logs that have fallen from the hillsides above. The soil of the hillsides is rocky glacial till, but the soil of the floor of the ravine is rich black humus. The stream begins at the western end of the ravine and flows eastward, gathering the water of many tiny springs. The stream disappears underground from time to time, to reappear a few feet further on, keeping the ground wet and marshy.

The ravine described above is called area A. Two similar ravines, areas D and E, situated $\frac{1}{4}$ and $\frac{1}{2}$ mile north, respectively, of area A, were used as control areas. Both are similar to area A, except that they are larger and have more coniferous timber and more and larger raised places. Both contain larger streams than area A, and neither is well bounded by hills. The flora and fauna are very similar to that of area A. While the small mammal population of area A fluctuated widely, that of the control areas was relatively stable.

The mammals present in area A during the time of study may be considered as belonging to three groups. The first group includes the casual visitors, consisting of the eastern gray squirrel, *Sciurus carolinensis*, introduced on the campus, which visits the area on rare occasions; the chipmunk, *Eutamias t. townsendii*, a common visitor from the hillsides; the house rat, *Rattus nor-*

vegicus, twice taken in the area; and the house cat, *Felis catus*, observed several times. All these may be predators that possibly effect the small mammal population. The most common predator in the area is the Kennicott screech owl, but the effect of this bird is also unknown.

A second group includes the rare residents: the coast mole, *Scapanus o. orarius*, a few workings seen from time to time; the mountain beaver, *Aplodontia rufa rufa*, trapped out in 1938 and never reestablished; the jumping mouse, *Zapus trinotatus*, and the meadow mouse, *Microtus oregonus*, of which two or three of each are taken each year. The runways and burrows of the mountain beaver seem to play an important part in the distribution of small mammals on the area, but since these were present, although the animal had disappeared, the area may be considered normal in this respect.

The third group of mammals include the common residents, the deermouse, *Peromyscus maniculatus austerus*; the shrew mole, *Neurotrichus gibbsii gibbsii*; and two shrews, *Sorex vagrans vagrans*, and *Sorex trowbridgii trowbridgii*. The following is concerned with the ecological relationships of these four mammals.

Sorex vagrans and *Neurotrichus* are typical residents of dark, marshy, wooded areas. *Sorex vagrans* seems unable to exist far from water and only two of several hundred specimens trapped by the writer were taken in dry woods, and these two were in woods close to water. *Neurotrichus* is able to live in dry woods, or even logged off or burned-over land, but they are never as common as in damp ravines. *Sorex trowbridgii* is usually the most common shrew in dry fir woods, although it is sometimes less common than *Sorex obscurus setosus*. *Sorex trowbridgii* is able to exist in marshy areas, and under such conditions is more numerous than in dry woods. If *Sorex vagrans* is present in the marshy situation, *Sorex trowbridgii* is absent or present only in small numbers. If *Sorex trowbridgii* is present, *Sorex vagrans* is almost never found there. Apparently these two species compete. Small sphagnum bogs, surrounded by fir woods in which *Sorex trowbridgii* is abundant, may contain only *Sorex vagrans*.

The writer believes this results from a difference in the breeding habits of the two species. *Sorex trowbridgii* breeds but once a year, late in April and early in May. Two pregnant females contained four embryos each. *Sorex vagrans*, on the other hand, breeds in all months of the year and embryos found vary in number from five to eleven. As far as could be determined *Sorex vagrans*, *Sorex trowbridgii*, and *Neurotrichus* eat the same type of food. *Neurotrichus*, being a burrowing form, could exist in the ravine in spite of competition with *Sorex vagrans*.

Trapping was begun in area A in February, 1937, and continued for two weeks, in which time 50 traps caught but one or two mammals a night. The *Peromyscus* population at this time had been reduced to zero. During this period the small mammal population was found to be normal for such an area.

The average *Peromyscus* population for the five acres was found to be about 200. After the removal of the *Peromyscus* the less common insectivors, *Neurotrichus* and *Sorex* were taken. Much trapping in area A, control areas D and E, and other similar ravines in western Washington, indicate that the normal ratio between *Peromyscus* and the small insectivors is about fifteen *Peromyscus* to one small insectivore. The ratio between the small insectivores themselves varies widely, but averages about five *Sorex* to one *Neurotrichus*. As previously stated for marshy areas, if *Sorex vagrans* is present, *Sorex trowbridgii* is rare or absent; if *Sorex trowbridgii* is common, *Sorex vagrans* is almost never present.

Trapping was resumed in the area on April 1, and continued for 20 days. *Peromyscus* had reinvaded the area from the hills, but the population was relatively small—about 40 individuals. The area contained 27 *Sorex vagrans*,

TABLE 1.—*Trap records in Area A*

DATE	DAYS TRAPPED	PEROMYSCUS	SOREX V.	SOREX T.	NEUROTRICHUS
March, 1937	14	221	14	0	3
April, 1937	20	43	27	0	5
Nov., 1938	15	245	15	0	5
Feb., 1938	11	64	21	0	4
April, 1938	15	30	9	0	6
May, 1938	19	31	13	0	34
Feb., 1939	14	197	17	0	4
March, 1939	10	41	10	0	2
Feb., 1940	13	201	13	0	5
March, 1940	9	100	0	1	4
April, 1940	30	73	1	1	10
July, 1940	10	57	0	12	1

a vast increase over the normal ratio. Trapping was stopped on April 20, and not resumed until the following fall.

In November, 1938, the area again had its normal population. It was again trapped down close to zero. Trapping in February, 1938, showed an increase in *Sorex vagrans*, a ratio of three *Sorex vagrans* to seven *Peromyscus*. The ratio of *Neurotrichus* to *Sorex vagrans* was slightly higher, about one *Neurotrichus* to four *Sorex*.

Trapping from April 1 to 15, 1938, showed an extremely low *Peromyscus* population, only two *Peromyscus* to one insectivore. *Sorex vagrans* was still the dominant insectivore but the *Neurotrichus-Sorex* ratio was much higher, about two to three. From May 1 to 19, 1938, the *Neurotrichus* population equaled the *Peromyscus* population and outnumbered the *Sorex vagrans* population 34 to 13. Trapping was not resumed until February 15, 1939. At this time the normal ratio again existed. Trapping was continued until the population was near zero. One month later the *Peromyscus-Sorex vagrans-Neurotrichus* population was about 20-5-1.

In February, 1940, the population ratio was again normal. It was trapped to near zero. By March the *Peromyscus* outnumbered the *Neurotrichus* 25 to 1, and no *Sorex vagrans* was taken. For the first time *Sorex trowbridgii* were taken in the ravine, although they had been present in small numbers on the hills above during the entire four years. In April, 1940, *Neurotrichus* was again abundant, with a ratio of seven *Peromyscus* to one *Neurotrichus*. A single specimen each of *Sorex vagrans* and *Sorex trowbridgii* was taken. At this time the area received the heaviest trapping in its history, and it is thought that all populations, except possibly *Neurotrichus*, were removed completely. Trapping was resumed June 26, 1940. *Sorex trowbridgii* was then the dominant insectivore and existed in a ratio of five *Peromyscus* to one *Sorex trowbridgii*.

The above observations suggest that the normal number of small insectivores in the ravine studied is proportional to the number of *Peromyscus* present, the *Peromyscus* population being constant, the small insectivore population is constant. The removal of *Peromyscus* disturbs the balance, and the small insectivores increase to a relatively high population.

When the population was reduced to near zero, *Peromyscus*, detecting the traps much easier, were reduced to absolute zero. The increase in the insectivore population probably results partly from increased breeding of the remaining stock, more complete litter survival because of the removal of competition, and invasion. *Peromyscus* reinvade the area following removal and tend to bring the population back to normal.

The three small insectivores compete with each other, and *Sorex vagrans* dominates *Sorex trowbridgii*. *Neurotrichus*, securing at least part of its food underground, is able to exist in the same locality as *Sorex vagrans*. *Sorex vagrans* is easier to trap out than *Neurotrichus*, and the great increase in *Neurotrichus* in 1938 probably resulted from the almost complete removal of *Sorex vagrans*. The great increase in *Sorex trowbridgii* in July, 1940, is thought to be caused by the complete removal of *Sorex vagrans* just preceding the breeding season of *Sorex trowbridgii*. *Sorex trowbridgii*, being present in the woods above, could easily invade the area.

The above may suggest a method by which collectors can procure a large series of relatively rare mammals from a single locality. It may be possible, by selective trapping, to manipulate populations of certain small mammals at will.

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THE CALIFORNIA RED-BACKED MOUSE IN THE OREGON COAST RANGE

By James A. Macnab and Jane Claire Dirks

Red-backed mice, genus *Clethrionomys*, have a wide geographical distribution that is circumpolar in extent and embraces the northern parts of Europe, Siberia, and North America. The range of the North American species is limited to Alaska, Canada, and the colder parts of northern United States and mountainous areas which extend southward (Bailey, 1897).

In 1928 the generic name *Evotomys* by which Coues had designated these mice in 1874 (Coues, 1874) was replaced by the name *Clethrionomys*, which had been assigned to the genus in 1850 by the German author Tilesius (Palmer, 1928).

Miller (1896) placed the red-backed mice in the subfamily Microtinae which includes the voles and lemmings. These are Cricetine rodents with flat-crowned molars and a prismatic molar pattern, composed of angular figures. A few of the species of red-backed mice superficially appear very much like some of the species of *Microtus*, and these forms can be distinguished only by careful examination. The resemblance of red-backed mice to other members of the subfamily is less striking. The red-backed mice are essentially forest dwellers, living in cool, damp localities.

In his revision, Bailey (1897) stated that the genus is uniform throughout North America; no widely divergent forms appeared in the material he had at hand. In that publication he ascribed four species to the state of Oregon. Subsequently, however, Bailey (1936) grouped three of them in the species *Clethrionomys californicus* (Merriam), leaving in Oregon *Clethrionomys gapperi idahoensis* (Merriam) (see Davis, 1939) and *C. californicus* with its three subspecies: *C. c. californicus*, *C. c. obscurus*, and *C. c. mazama*. *C. gapperi idahoensis* is found in northeastern Oregon in the Blue Mountain region. This species is an inhabitant of open pine and spruce forests. The three subspecies of *C. californicus* occupy the western portion of the state, with *C. c. mazama* occurring in the forests along the summit of the Cascade Mountains, *C. c. obscurus* inhabiting the lower flanks of the mountains and the more open areas between the heavy timber of the humid Coast Range and the Cascades, and *C. c. californicus* dwelling in the forested portions of the humid coastal area. It is with the last of these subspecies that this paper is chiefly concerned.

THE CALIFORNIA RED-BACKED MOUSE IN OREGON

Previously published records.—In 1890 Merriam first described the California red-backed mouse, *C. californicus*, designating as the type specimen one collected by T. S. Palmer at Eureka, Humboldt County, California, on June 3, 1889 (Merriam, 1890). According to Bailey (1936), individuals of

this species are large, dark-colored, long-tailed red-backed mice "in which the red of the back is much obscured or sometimes wholly concealed by black." The color of adults is "deep chestnut over the back, much obscured by dusky hairs; sides dark buffy gray; belly buffy or ochraceous over dark underfur; toes white or whitish; tail indistinctly bicolor, dusky above, whitish below. Young much darker, sometimes almost black." Measurements are as follows: "average of typical adults, total length, 165 mm; tail, 53; foot, 20.5; ear (dry), 10."

Until recently this mouse has been reported from only four localities in the state of Oregon: Astoria, Yaquina Bay, Wells, and Oregon City (Bailey, *ibid*). Even in these localities red-backed mice have been trapped rarely and only a few specimens have been recorded (Table I). While the occurrence of *Clethrionomys* in the interior Coast Range has been postulated, records of capture there have not been reported previously. Knowledge of their range, habits, and life history has been very limited, and, as stated in Bailey (*ibid.*), little has been known of their reproductive cycle.

Occurrence in the interior Coast Range.—In the course of research investigations conducted on Saddle Mountain in the Coast Range in northeastern Lincoln County, Oregon, four specimens of *C. c. californicus* have been collected by the authors. Three of them (nos. 12, 43, and 44) were taken on an old sea terrace on the mountain at an elevation of about 1400 feet. The other one (no. 25) was secured at an elevation of approximately 2500 feet. In general the vegetation of Saddle Mountain is similar to that throughout the Coast Range of Northwestern Oregon. The dominant trees are Douglas fir (*Pseudotsuga taxifolia*), which commonly attain a height of 200–250 feet with a diameter of 4–6 feet, and western hemlock (*Tsuga heterophylla*), which average about 2–3 feet in diameter and 150 feet in height, reaching up to the lower branches of the Douglas fir crowns. Young hemlock seedlings form still another layer beneath the mature hemlock crowns. Giant cedar trees (*Thuja plicata*) rival or perhaps excel the Douglas firs in diameter on Saddle Mountain but they occur much less commonly, usually as scattered groups of trees chiefly in proximity to the streams although they extend well toward the top of the mountain. The Douglas fir and hemlock trees form a dense cover over the greater part of the mountain with Oregon maple (*Acer macrophyllum*) and vine maple (*Acer circinatum*) comprising a lower layer of trees in the more open areas and along streams where the Oregon alder (*Alnus oregana*) also grows in abundance.

In undisturbed climax and late subclimax areas on the mountain, the shrub layer consists of scattered huckleberries (*Vaccinium ovalifolium* and *V. parvifolium*), which alternate with the lower Oregon grape (*Berberis nervosa*), salal (*Gaultheria shallon*), and sword fern (*Polystichum munitum*), while in more moist, open, or disturbed areas, which are younger from the standpoint of succession, dense tangles of bracken (*Pteridium aquilinum pubescens*) or

salmonberry (*Rubus spectabilis*) and thimble berry (*Rubis parviflorus*) commonly occur with scattered groups of Devil's club (*Echinopanax horridum*). The following species of herbaceous plants are common: *Oxalis oregana*, vanilla-leaf (*Achlys triphylla*), *Clintonia uniflora*, false Solomon's seal (*Vagnera sessilifolia*), and *Disporum smithii*. Few of these grow to a height of more than a few inches, but they contribute very markedly to the seasonal aspect of the forest floor, which, otherwise, is uniformly carpeted with mosses except where a dense canopy of hemlocks inhibits their growth.

On July 29, 1936, the first specimen of *Clethrionomys* (no. 12), an immature male, was caught in a snap-trap baited with cheese and set on moss in a thicket of bracken and thimble berry. The measurements of this animal (total length, 98 mm; tail, 32 mm; hind foot, 17 mm), by comparison with related mice for which the growth rate is better known, indicate that it was only a few weeks old. This would mean that it came from a litter born about the first or middle of June. This mouse was caught in an area that had been cleared for a cabin by a homesteader about thirty years previously. A few years later the property of all settlers on the mountain was purchased by a lumber company, and the natural processes of plant succession had been permitted to proceed with very little disturbance since that time.

The second mouse (no. 25) was obtained on January 2, 1937, at an elevation of nearly 2500 feet—the highest elevation on record for *C. c. californicus* in Oregon. This specimen, a male in winter pelage, was secured in an unbaited steel trap set in fine rotten wood in the center of a cedar stump in which it may have had its nest. It was taken in the most completely climax situation of any of the mice trapped on Saddle Mountain, for mature trees of both cedar and hemlock were present. Its measurements were: total length, 155 mm; tail, 50 mm; hind foot, 20 mm. The color and general appearance of this mouse indicated that it was probably a young adult.

The third and fourth specimens (nos. 43 and 44, respectively) were caught on August 27, 1937, in traps set beside burrows in the ground, indicating possible subterranean habits. These were both in summer pelage. Number 43 was a female containing four embryos averaging 2 to 3 mm in diameter. The total length of this animal was 155 mm; tail, 56 mm; hind foot, 19 mm. The other mouse was partially eaten by ground beetles, making it impossible to determine its sex. It evidently was an adult, as indicated by the measurements (total length, 155 mm; tail, 46 mm; hind foot, 19 mm). Only the skull of no. 44 was saved. These two mice were taken in an area of the forest which is late subclimax—Douglas firs and hemlocks were the dominant trees — and has never been disturbed by man.

The authors are indebted to Stanley G. Jewett, Fish and Wildlife Service, Portland, Oregon, for the identification of these specimens. Mr. Jewett stated that they were the first of the species to be secured in the interior Coast Range mountains of Oregon. The skins of the first three mice, nos. 12, 25,

and 43, are in the research collection at Linfield College, McMinnville, Oregon.

TABLE 1.—*Summary of records of Clethrionomys californicus californicus (Merriam) in the state of Oregon*

	LOCALITY	DATE	COLLECTOR AND SOURCE	SEX	MEASUREMENTS
1	Oregon City (Clackamas Co.)	Oct. 17, 1893	C. P. Streator, Biol. Surv., no. 56906	Imm. ♀	145–46–18
2	Yaquina Bay (Lincoln Co.)	June 14, 1895	B. J. Bretherton, Biol. Surv., no. 72385	Ad. ♂	163–55–20
3	Astoria (Clatsop Co.)	July 19, 1897	A. K. Fisher, Biol. Surv., no. 89130	Ad. ♀*	155–48–20
4	Astoria (Clatsop Co.)	July 20, 1897	A. K. Fisher, Biol. Surv., no. 89131	Imm. ♂	135–42–20
5	Astoria (Clatsop Co.)	July 21, 1897	A. K. Fisher, Biol. Surv., no. 89132	Imm. ♂	131–40–20
6	Wells (Benton Co.)	Dec. 4, 1904	N. Hollister, Biol. Surv., no. 135254	Imm. ♂	143–48–18
7	Saddle Mt. (Lincoln Co.)	July 29, 1936	J. A. Macnab, Coll., no. 12	Imm. ♂	98–32–17
8	Saddle Mt. (Lincoln Co.)	Jan. 2, 1937	J. A. Macnab, Coll., no. 25	Ad. ♂	155–50–20
9	Saddle Mt. (Lincoln Co.)	Aug. 27, 1937	J. A. Macnab, Coll., no. 43	Ad. ♀†	155–56–19
10	Saddle Mt. (Lincoln Co.)	Aug. 27, 1937	J. A. Macnab, Coll., no. 44	Ad. ?	155–46–19
11	Estacada (Clackamas Co.)	Dec. 29, 1931	S. G. Jewett, Jr., Coll., no. 322	♀	120–40–17
12	Estacada (Clackamas Co.)	No data	Jewett (M. S.)	—	—
13	Taft (Lincoln Co.)	Feb. 22, 1932	S. G. Jewett, Jr., Coll., no. 385	♀	143–47–20
14	Delake (Lincoln Co.)	June 8, 1933	S. G. Jewett, Jr., Coll., no. 563	♀	153–48–19
15	Delake (Lincoln Co.)	No data	Jewett (M. S.)	—	—
16	Tillamook (Tillamook Co.)	Feb. 24, 1928	Alex Walker	♀	145–44–20
17	Tillamook (Tillamook Co.)	Nov. 12, 1928	Alex Walker	♀	150–49–19.5
18	Netarts (Tillamook Co.)	Feb. 9, 1933	Alex Walker	♀	142–49–20.5

* Two embryos.
† Four embryos.

Additional new records for the state.—Through correspondence with Stanley G. Jewett, Jr., of Portland, Oregon, and Alex Walker, Tillamook, Oregon, the authors have secured the following supplementary records of capture of the California red-backed mouse in Oregon.

A specimen was taken December 29, 1931, by S. G. Jewett, Jr. at Camp Millard near Estacada, Oregon. It was caught in a snap-trap, baited with rolled oats, set on a rocky hillside beside a Douglas fir log. Cover was comparatively scarce, vine maple and scattered Douglas firs comprising the dominant vegetation on the hillside. *Peromyscus maniculatus rubidus* Osgood was abundant at this location. At least one other red-backed mouse has been collected at the Estacada locality by a friend of Jewett, but the specimen has been lost.

A second specimen, female, was taken by Jewett February 22, 1932, near Taft, Oregon, in a dense stand of hemlock. The trap, baited with rolled oats, was set beside a rotten log. Shrews—*Sorex t. trowbridgii* Baird and *S. obscurus bairdi* Merriam—were numerous at the site. *Peromyscus* were unusually scarce, only two being taken in some sixty sets.

A third specimen, female, was taken by Jewett at Delake, Oregon, June 8, 1933. This mouse was trapped in a stand of spruce on a high bluff overlooking the ocean about one-half mile south of the mouth of Devil's Lake. The trap, baited with rolled oats, was set in the underbrush beneath the spruces. *Microtus o. oregoni* (Bachman) and *Peromyscus* were the more abundant animals at this location. One or two additional specimens were collected at Delake by a friend of Jewett but data regarding them are not available. The three mice collected by Jewett are now in the collection of the Cleveland Museum of Natural History.

The information available on a small series collected by Walker is more fragmentary. All are females. The first specimen was collected on February 24, 1928, at Tillamook, Oregon; the second at Tillamook, on November 12, 1928; and the third was secured February 9, 1933, at Netarts, Oregon.

DISCUSSION AND SUMMARY

Although data concerning the nature of the communities in which the California red-backed mice occur are incomplete for the specimens reported in this paper, a few interesting facts have been revealed. Bailey (*ibid*) refers to the California red-backed mouse as occurring "mainly in heavy forests of humid Transition Zone," living "mainly on the ground." An examination of the data here presented shows that these mice occur in mixed stands of cedar and hemlock, Douglas fir and hemlock, and Douglas fir, hemlock, and spruce separately. Cover may vary from "comparatively scarce" to "dense" but always, as far as the data reveal, they are restricted to forested areas. In ecological terminology they would be classed as permeant animals because they occur in seral communities of the biome as well as in the climax. Their habitats range from near the ocean to elevations of approximately 2500 feet in the Coast Range, and they occur as far inland as the west slope of the Cascade Mountains in the Willamette Valley at an elevation of approximately 500 feet (Estacada) and the east slope of the Coast Range Mountains in Benton County (Wells, elevation 223 feet).

Some of the red-backed mice were caught beside fallen logs which probably afforded shelter for their nests; others were taken in areas of bracken, thimble berry and other shrubby plants; two apparently came from burrows in areas more free of shrubs and low plants; and one was secured in a large cedar stump where it may have had a nest in the rotten wood. Bailey (*ibid*) says that these animals are generally caught under old logs in the woods.

The authors gained little information regarding the food habits of these mice beyond that given in Bailey (*ibid*); "They feed largely on green vegetation, grass, seeds, and various small plants. They are eager for rolled oats or any kind of grain used for trap bait." They also take cheese.

The investigations carried on by the authors showed the white-footed mouse (*Peromyscus maniculatus rubidus*) to be the most abundant small mammal in the area. Jewett also found this species common in the localities where he secure red-backed mice, except in the one coastal area near Taft. He noted that *Sorex t. trowbridgii* and *S. obscurus bairdi* were numerous at this locality. The authors also secured *Sorex t. trowbridgii* on Saddle Mountain though not in large numbers. Jewett (M. S.) reported *Microtus o. oregoni* as a common species in the Delake community.

Only two pregnant females of the California red-backed mouse have been obtained. One of them was taken on July 19, 1897, by A. K. Fisher at Astoria, Oregon, and contained two embryos, averaging about 10 mm in diameter. The second specimen was taken by the authors on August 27, 1937, on Saddle Mountain; she contained four embryos, averaging approximately 3 mm in diameter. No definite conclusions can be drawn regarding the number of mice in a litter from so few records, but the indication is that the number varies from two to four or possibly more. A summary of the records (Table I) shows that breeding occurs over a rather extended period with young probably being born from late May to October.

It is the opinion of the authors that more specimens of *Clethrionomys* have not been obtained because the life history of these animals is not well known. A majority of the sets made in the course of the investigations on Saddle Mountain were in places more favorable for the capture of *Peromyscus* than *Clethrionomys*. Continued efforts and patience might well be rewarded with many more specimens. Thus, *Clethrionomys* may prove to be a relatively common rather than a "rare" inhabitant of the Oregon Coast Range forests.

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EFFECTS OF HIBERNATION ON THE RATE OF OXYGEN CONSUMPTION IN THE THIRTEEN-LINED GROUND SQUIRREL

BY FRANCIS MARSH BALDWIN AND KENNETH LEROY JOHNSON

Previous studies indicate a general reduction of physiological activities during hibernation in this rodent. Johnson (Quart. Rev. Biol., 1931) reported that the average heart rate per minute ranged from an average of two hundred beats in the normal active animal to an average of seventeen beats in torpid animals whose environmental temperatures were below 10°C. Likewise it was reported that in some instances the body temperature dropped from 40°C to 4°C as the environmental temperature approached 0°C. The body temperature during hibernation averaged approximately 2°C higher than the environment in practically all observations. It was also reported that the normal average respiratory rate of one hundred and eighty-seven was reduced to a rate of four per minute in deeply torpid animals. Pfeiffer, Foster, and Slight (Jour. Pharmacol. and Exper. Therap., 1939) report substantially the same levels of respiratory activity in the normal and the hibernating conditions of these mammals.

In the study here reported, a series of experiments were designed to determine in more finite and critical quantitative detail the metabolic accompaniments of these physiological changes since no such data are as yet available in the literature on this form.

Two male ground squirrels were brought to the laboratory from their burrows after they had entered upon their normal winter sleep in December, 1939, and were used in a series of experiments during the period from January through March, 1940. Specimen A had an average weight of approximately 78 grams during the course of the experiments and was judged to be young and less mature than Specimen B, whose weight averaged 101 grams during the same interval. The animals were kept in a screened cage in a quiescent condition under controlled temperatures for two days before a series of quantitative measurements were begun, to insure basal conditions. In each series of procedures the animals were run successively under similar conditions and controlled experimental environmental temperatures.

The apparatus and methods used were those described by Tainter and Rytand (Proc. Soc. Exper. Biol. and Med., 1934–35) suited to measure the oxygen consumption of small animals. Seventy-seven trials were taken at the controlled environmental temperatures, and this data, together with pertinent observations of O_2 consumption, are included in table 1.

As indicated, Specimen A, when subjected to an average environmental temperature of 21.4°C, consumed oxygen at an average rate of 1.774 cc per gram per hour. When the temperature was lowered to 12.5°C, the rate of oxygen consumption during the experimental run averaged 0.197 cc per gram per hour. When the temperature was lowered and held experimentally at 8.6°C, the oxygen consumption approximated an average of 0.125 cc per gram per hour. This represents a decrease of 92.25 per cent in oxygen consumption from the experimental room temperature level and this rate proved to be critically close to lethal for the species. In a series of ten observations

TABLE 1.—*Oxygen consumption as determined for Citellus tridecemlineatus (Mitchell) at different hibernation temperature levels*

SPECIMEN	AV. ENV. TEMP.	NO. OF TRIALS	AV. WT.	AV. RESP. PER MIN.	AV. CONS. O_2 GR. HR.
	°C		grams		cc
A	21.4	11	79.12	134.4	1.774
B	21.6	10	101.88	141.5	1.344
A	12.5	11	75.58	1.8	0.197
B	12.7	11	104.78	5.8	0.218
A	8.6	6*	82.266	1.6	0.125
B	8.9	11	104.6	4	0.191
B	8.1	13	104.716	2.3	0.161
B	4	4†	94.45	1	0.081

* Died on 6th.
† Died on 4th.

under similar conditions (21.6°C), specimen B consumed oxygen at an average of 1.344 cc per gram per hour. When subjected to a temperature of 12.7°C the oxygen consumption dropped to an average level of 0.218 cc per gram per hour. When subjected to an experimentally controlled temperature of 4°C, the oxygen consumption was reduced to an average level of 0.081 cc per gram per hour. This represents a reduction in metabolic rate of 93.97 per cent before lethal conditions were reached, as the animal died during the fourth trial at this environmental temperature.

The decrease in rate of oxygen consumption at different levels during progressive stages of hibernation is a quantitative index to the extent of the reduction in the metabolic activities of the ground squirrel as it changes from the normal to the hibernating state. Although there was a reduction of approximately 93 per cent in oxygen consumption, there was, however, sufficient metabolic activity to maintain the body temperature of the subjects

at an average of 1.8°C higher than the surroundings. The critical lethal temperature below which metabolic exchanges can not be maintained in this form approximates 4°C. This study substantiates previous reports of decreased physiological activity during hibernation and extends the rather meager quantitative information relative to the level of metabolic activity of these mammals during progressive stages in hibernation.

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A BOX TRAP FOR THE CAPTURE OF LIVE GEOMYS

By H. B. Sherman

The trap described below was designed with the idea in mind that a pocket gopher objects to walking on a hard smooth surface, but will enter a trap if the floor seems to be the sandy soil of its burrow. Also it will attempt to plug an opening where light or a current of air enters its tunnel.

To meet these requirements, the trap is constructed so that the floor and back end consist of ½ inch mesh wire. The top and sides are made of a piece of sheet metal bent to make the body of the trap 3 inches square and 11 inches long. Folds along the bottom and back edges of this piece hold the wire mesh securely in place, as shown in the upper right corner of figure 1. A sheet metal door, hinged near the top and at the front end of the trap, is operated by a spring. When set, the door is held open by a trigger wire which is held to the under side of the top of the trap by 2 guides, through which it can slide for a short distance (see fig. 1). The trigger wire is turned down near the back end of the trap and bent into a triangular loop so that when the gopher tries to plug the opening of this end of the trap, it pushes the trigger wire away from the door, which closes to trap the animal. To provide more surface for the gopher to push against, the loop of the trigger wire is covered with a piece of sheet metal.

To set the trap, the door is held open and the front end of the trap turned downward which causes the trigger wire to slip into position to keep the door open. The open end of the trap is then placed against the exposed end of the gopher's burrow and worked back and forth until the sandy soil has worked through the wire mesh floor of the trap. Most of the trap is then covered with soil, but the back end is left uncovered to provide an opening for the pocket gopher to plug. In exposing the gopher's burrow, it is advisable to dig into it along its course, not at its end. For this reason it is usually necessary to set more than one trap, one at each of the newly made openings of the tunnel.

During the past 2 years these traps have caught the intended victim promptly under most conditions. When the soil is in such condition, however,

that the gopher moves an unusually large amount of it at one time, the trap may be filled without being sprung. The only solution the writer has found

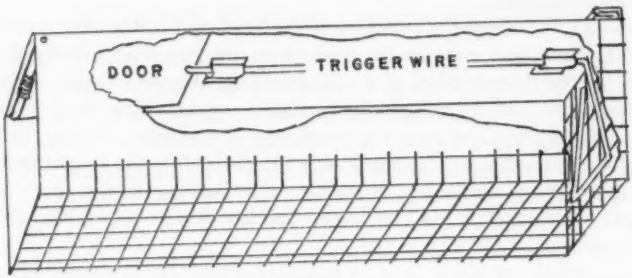

FIGURE 1

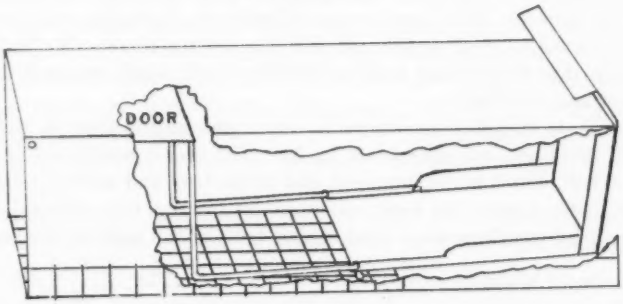

FIGURE 2

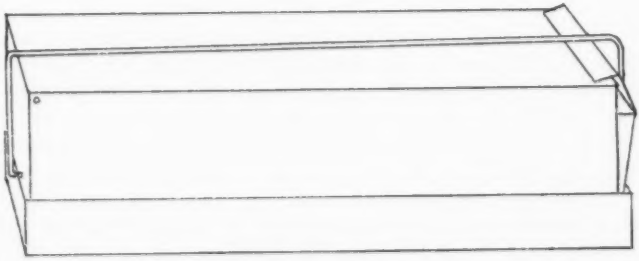

FIGURE 3

for this state of affairs is to wait for better weather conditions. On the other hand, young *Geomys* sometimes move such a small amount of earth at a

time that the trap is eventually filled without enough pressure being brought to bear on the trigger wire to release the door. To overcome this difficulty, the trap was modified.

As revised, the trigger mechanism is the back end of the trap as well as a part of the floor, and supports the door when the trap is set (see fig. 2). The support for the door consists of a stiff wire loop attached to the sheet metal of which the rest of the trigger mechanism is made. The sheet metal part is hinged at its front end near the lower part of the trap. When the trap is set, the trigger mechanism is almost counterbalanced by the weight and spring of the door. It is necessary, of course, when setting this type of trap, to leave plenty of space below the trigger mechanism to prevent interference with its motion.

Thus modified, soil can be pushed into the back of the trap, a little at a time, until enough weight has accumulated to overcome the resistance of the door, as a result of which the wire support slips back of the door and allows it to close. As a result, this trap is more effective in capturing small *Geomys*, and it is almost as good as the original style for large ones. It also has the advantage that it performs well in catching other small mammals such as *Sigmodon* and *Oryzomys*.

To facilitate shipping specimens, a watertight tray is used in which the trap and its captive are placed (see fig. 3). The trap is held in the tray by a stiff wire bail, which hooks into each end of the tray and serves as a handle. Provided with carrots for food, specimens of *Geomys* thus shipped usually arrive in good condition even after having been in the mail for several days.

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FOOD OF FERAL HOUSE CATS IN OKLAHOMA, A PROGRESS REPORT

By Frank B. McMurry and Charles C. Sperry

Feral house cats, even some that are tame and apparently well fed, frequent fields and roadsides and prey on various forms of wildlife. The word "feral" as used in this report applies to all field-roaming house cats even though some of the roadside victims included may not have been permanently living in the wild. The food obtained by these field-roaming cats is of special interest because it is commonly believed that birds are a dominant item in the diet. The present report, based on the examination of 107 house cat stomachs collected in Oklahoma over a three-year period (April 1937 to May 1940), presents factual data on the subject. Twelve of the 107 stomachs were empty and 11 more contained only traces of food, so percentage tabulations were based on the analyses of 84 stomachs. Sixty-three per cent of the cats taken were males. Analyses were made by the junior author in the Food Habits Laboratory of the United States Fish and Wildlife Service in Denver.

Because of intensive collecting on and near the Wichita Mountains Wildlife Refuge, where the senior author is stationed, and on the nearby Fort Sill Military Reservation, 70 per cent of the stomachs were from Comanche County, but 12 other counties of the State were represented in the remaining 30 per cent.

Acknowledgment of assistance is due Major O. F. Marston, in charge of the Fort Sill Game Farm, and Sergeant C. L. Roberts, superintendent of the farm, for stomachs of cats taken on the Fort Sill Military Reservation. Several federal and private trappers and refuge employees also coöperated by collecting stomachs. Coöperators preserved only the stomachs, but the senior author, who made many nightly forays for cats on and off the refuge and salvaged material from dead cats along the highways, frequently saved both stomach and intestinal contents.

The 84 stomachs available for this study fall naturally into three groups—those from the Wichita Mountains Wildlife Refuge (24), those from the Fort Sill Military Reservation (22 from residential sections and 13 from non-residential areas), and those from other localities in the State (25). The results of the analyses indicate the desirability of discussing each group separately before considering the entire lot of 84 stomachs together.

Group 1: Cats Collected on the Wichita Mountains Wildlife Refuge (24 stomachs).—This group includes feral cats as well as some household pets abandoned at camp grounds. Many of them were shot in camp grounds and a few were taken in traps set for coyotes.

Insects comprised 25.5 per cent of the food and sometimes they were taken in large quantities, especially in summer months. Orthopterous forms—short-horned grasshoppers, katydids, cave crickets, and field crickets— were

most frequently represented. Other insects eaten were a sawfly larva, a caterpillar, and a May beetle. Arachnids—a tarantula and a spider that occurred in 2 stomachs and comprised 1 per cent of the food, are included in the sector labeled "insects" in figure 1.

Lizards are varied and abundant on the refuge, so we were not greatly surprised to find them contributing appreciably to the local cat diet (4.5 per cent).

The remains of a large frog (*Rana*) in the intestines of a cat whose stomach was filled with garbage compose the only record of an amphibian in the food of these Oklahoma house cats.

Mammals, chiefly rodents, formed 54 per cent of the food of the refuge cats, and it was in this group of stomachs that the greatest variety of mammals was found. The cottontail, found in 6 stomachs and composing 14 per cent

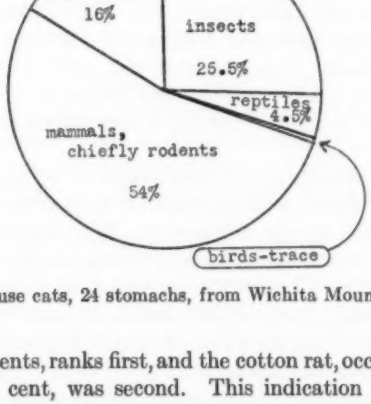

FIG. 1. Food of house cats, 24 stomachs, from Wichita Mountains Wildlife Refuge, Oklahoma.

of the stomach contents, ranks first, and the cotton rat, occurring in 3 stomachs and forming 9 per cent, was second. This indication that cottontails are abundant on the refuge and are more easily caught than other mammals is supported by the fact that they also form a large percentage of the food of other predators, both mammals and birds, on the refuge.

Garbage, chiefly such camp ground refuse as cooked potatoes, chicken skins, bread, egg shells, paper, charred bones, and charcoal, was found in 6 stomachs and composed 16 per cent of the total food.

Group 2, Cats Collected on the Fort Sill Military Reservation (35 stomachs). Twenty-two of the cats from Fort Sill were taken in residential sections and 13 from nonresidential areas. Most of them from residential sections were trapped during the fall of 1939 and probably include many so-called "alley cats" as well as a few house pets. Several were captured on the Game Farm, which is in residential surroundings. Those from nonresidential sections

were taken in traps set for fur animals during the 1938–39 trapping season and probably include a high percentage of truly feral cats.

The fact that all Fort Sill cats were taken in fall and winter (mid-October to mid-January) may account for the absence of amphibians and reptiles from their diet. The effect of environment on food habits is clearly indicated in figure 2.

Insects were not represented in the food of the more feral cats, but composed 17.5 per cent of the sustenance of those from residential sections. Forms taken were grasshoppers, field crickets, and cockroaches.

Two birds, an English sparrow and a meadowlark, formed the bulk of the last meal of 2 cats from residential sections and made an average of 6.5 per cent of the food for the lot. Only 1 of the 13 cats from nonresidential areas

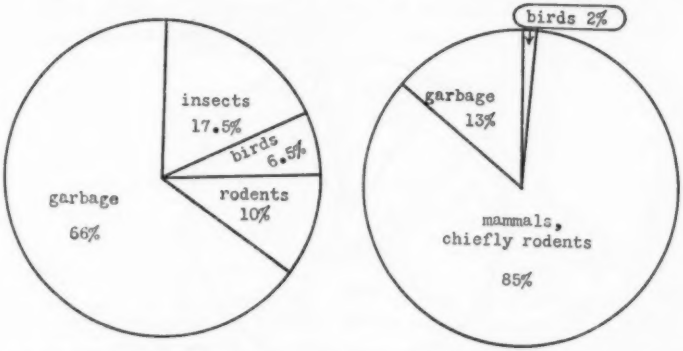

FIG. 2. Food of house cats, 35 stomachs, from Fort Sill Military Reservation, Oklahoma. Left side chart represents 22 stomachs from residential section; right side represents 13 stomachs from nonresidential sections.

captured a bird, a robin. Even so, three-fourths the contents of this stomach was composed of remains of a cotton rat.

Mammals, chiefly cotton rats, contributed 10 per cent to the food of the cats from residential sections and 85 per cent to that of the more feral cats. In the latter case, cotton rats constituted nearly four-fifths of the mammal food.

Garbage, as might be expected, was a major food item of those cats taken in a residential environment. The material composing this 66 per cent by volume was varied and included heads of chickens and ducks as well as cooked meats and vegetables and corn husks, paper, and cellophane. Garbage was found in only 1 of the 13 stomachs from the nonresidential area and it was composed of the dried flesh of a large mammal that may have been carrion, but was listed as garbage because the cat was trapped on an old dump.

Group 3, Cats Taken in Other Sections of Oklahoma (25 stomachs).—The

The 25 stomachs comprising this group came from 12 counties. They were collected throughout the year and probably include some domestic house pets that were hunting along roadsides at night as well as more feral individuals.

Insects, chiefly grasshoppers and crickets, composed 2.5 per cent of the food. A spider was found in 1 stomach, but it formed less than 1 per cent of the contents.

A spotted lizard (*Holbrookia maculata*) made 35 per cent of the meal of one cat and resulted in a reptile food average of 1.5 per cent for the entire group.

Birds composed 6 per cent of the food and occurred in 5 of the 25 stomachs. Remains of 3 birds—a Brewer's blackbird, a horned lark, and a meadowlark—were found in one stomach collected in February, even though 25 per cent of

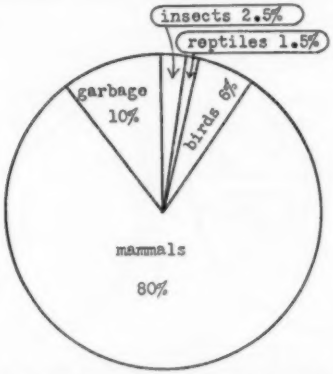

FIG. 3. Food of house cats, 25 stomachs, from sections of Oklahoma other than Wichita Mountains Wildlife Refuge and Fort Sill Military Reservation.

the contents was cotton rat. Other birds identified were a flicker, a longspur, and a red-bellied woodpecker.

Mammals, chiefly cotton rats and rabbits, comprised 80 per cent of the food of this group of cats. Cotton rats (39 per cent) were found in 15 stomachs, and cottontail rabbits (31 per cent) in 12. Other mammals of note were house mice, that occurred 3 times and formed 6 per cent of the food, and wood rats, which occurred only once but contributed 4 per cent by volume.

Garbage, found in three stomachs, constituted 10 per cent and included such varied items as bologna, fish bones, a chicken foot, cooked meat, cracked wheat (probably cereal), an apple core, and cellophane.

DISCUSSION OF COMBINED MATERIAL

Insects, chiefly grasshoppers and crickets, eaten by Oklahoma house cats throughout most of the year, formed 12.5 per cent of their food. Spiders were occasionally taken, but contributed less than one per cent to the total diet.

Amphibians, apparently, are rarely devoured by cats because this study revealed only one, a frog. Lizards, on the other hand, were frequently consumed and formed 2 per cent of the food. Forms identified were collared lizards, a spotted lizard, and a spiny lizard. Snakes were not eaten.

Birds were found in 9 stomachs and composed 4 per cent of the food. No game birds were eaten and the meadowlark was the only species of bird that occurred more than once.

Mammals formed 55 per cent of the total food. Half of this volume was composed of cotton rats, an injurious species, and a fourth of it of cottontail rabbits. Other mammals eaten were brown rat, deer mouse, house mouse, mole, pocket mouse, short-tailed shrew, 13-lined ground squirrel, and wood rat.

Garbage composed 26.5 per cent of the food of the 84 cats included in this study. Part of this volume probably would be replaced by carrion in the diet of cats taken where less garbage was available.

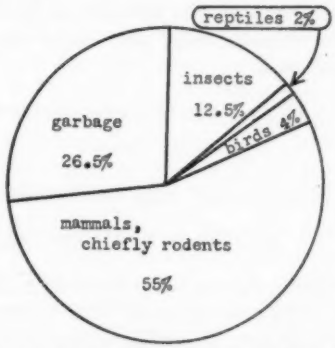

FIG. 4. Food of house cats, 84 stomachs, from all sections of Oklahoma.

Green grass occurred in six stomachs, but never in measurable quantity and its role in the diet of cats is unknown. Perhaps it may aid in clearing the intestinal tract of parasites. Many of the cats examined were heavily parasitized with roundworms and tapeworms.

SUMMARY

Laboratory analyses of 84 Oklahoma house cat stomachs revealed 3 main foods, namely, insects, mammals, and garbage. Reptiles and birds were minor items.

Insects contributed 17 and 25 per cent, respectively, to the food of cats collected on the Wichita Mountains Wildlife Refuge and in the residential section of the Fort Sill Military Reservation, but much less to the diet of cats from other sections.

Mammals, chiefly rodents, composed from a half to four-fifths of the food

of the cats in each habitat group except those collected in the residential section of Fort Sill where they made up only 10 per cent of the diet.

Garbage formed two-thirds of the food of the cats collected in the residential areas on Fort Sill. In other environments it was from 10 to 16 per cent of the food.

Lizards formed 4.5 per cent of the food of cats from the Wichita Mountains Wildlife Refuge, but they were not taken at all by the Fort Sill cats and comprised only 1.5 per cent of the food of the cats collected in other sections.

Birds comprised 6.5 and 6 per cent, respectively, of the food of cats taken in the residential district of Fort Sill and of those obtained here and there along highways of the State. They occurred only once each in the two groups of cat stomachs representing the Wichita Mountains Wildlife Refuge and the nonresidential area of Fort Sill. In other words, cats of residential areas and those frequenting roadsides appear to be a greater menace to birds than cats hunting in open fields or woods. The data at hand, however, indicate that the prey of cats consists largely of the most abundant and available forms and do not justify the common belief that every roadside or field-roaming cat is in search of avian food.

U. S. Fish and Wildlife Service, Cache, Oklahoma, and Denver, Colorado.

THE TYPE SPECIMEN OF MEPHITIS FRONTATA COUES

By Gerrit S. Miller, Jr.

When listing the remains of mammals collected by Baird in Pennsylvanian caves (Journ. Mamm., vol. 21, no. 3, pp. 319–322, August 14, 1940) I neglected to mention the skunk skull from Dale's Cave, near Lewisburg, Union County, to which Coues, in 1875, applied the name "*Mephitis frontata* n. sp. foss." (Bull. U. S. Geol. and Geogr. Surv. Terr., ser. 2, no. 1, p. 7, fig. 1, probably before May 14, the date of no. 2).

This skull, that of an old individual, undoubtedly a male, with very high sagittal and lambdoid crests, is well preserved. Its lower jaw is complete. All of its teeth are present except four incisors (i^3 left, i^2 right, i_1 right and i_3 right). The fragile turbinate bones are in perfect condition. Nowhere is there any trace of mineralization. The entire surface is somewhat stained (more noticeably above than below) as if by damp cave earth; but the palate, the mandibles and the teeth are almost clean.

There is no justification for the idea that the skull is geologically old. Nevertheless both Coues and Howell regarded it as a "fossil". Coues expressed his belief by the mere indication: "*Mephitis frontata* Coues n. sp. foss." (p. 7.) Howell was more explicit. He wrote: "The form described by Coues under this name [*frontata*] was based on a skull found in the Post-

pliocene deposits of Pennsylvania. While the characters assigned to it by him are of slight weight, it differs from the living species ["*putida*" = *nigra*] in dental characters, and seems worthy of specific recognition" (North Amer. Fauna, no. 20, p. 16, August 31, 1901).

After carefully examining the specimen I am unable to find a good reason to regard it as anything else then the skull of a large old male of the common eastern skunk, *Mephitis nigra*, with the frontal sinuses excessively inflated (see the figure published in the original description) as the result of infestation by some parasite (probably one or the other of two nematode worms, *Skrjabingylus nasicola* and *S. chitwoodorum*, according to information given me by Doctor E. W. Price, Assistant Chief, Zoological Division, Bureau of Animal Industry, U. S. Department of Agriculture).

The skull is in the same state of preservation as many of the other bones of recent mammals found by Baird in the Pennsylvanian caves. Its size is not significantly greater than that of the skull of a freshly killed immature male skunk (no. 670) that he collected near Carlisle. It is rather noticeably exceeded in size by the skull of an adult male (no. 188553) taken in the Adirondacks, New York, and identified by Howell (1901, p. 27) as "*Chincha putida*" (= *Mephitis nigra*). The form of the posterior edge of the bony palate is more like that usually seen in *Mephitis mephitis* and *M. hudsonica* than like that found in most specimens of *M. nigra*; but several skulls of *M. nigra* (for instance, nos. 123528 and 123541 from Rhode Island, no. 253833 from Massachusetts, and no. 219902 from Naskeag, near Brooklin, Hancock County, Maine, a locality from which Howell, 1901, p. 27, recorded "*Chincha putida*") have the median projection of the palate imperfectly developed in much the same manner as it is in the type of *M. "frontata."* Measurements (those in parenthesis are taken from the following specimens of *Mephitis nigra*: no. 670, Carlisle, Pennsylvania, no. 125541, Washington County, Rhode Island, and no. 219902, near Brooklin, Hancock County, southern Maine): condylobasal length, 73.4 (71.2, 70.0, 79.4); palatal length (including incisors), 29.0 (30.0, 28.8, 30.2); mastoidal breadth, 41± (39.0, 39.6, 42.0); interorbital breath at lacrimal level, 23.6 (22.6, 23.6, 25.0); rostral breadth at level of canine alveoli, 20.6 (19.8, 19.6, 21.2); mandible, 51.0 (47.0, 49.0, 51.4); depth of mandible (through coronoid process), 26.0 (23.0, 22.4, 26.0); depth of mandible at posterior root of carnassial, 9.0 (9.0, 9.0, 8.9); maxillary toothrow (alveoli), 20.6 (22.0, 22.0, 23.0); mandibular toothrow (alveoli), 28.0 (27.5, 29.0, 28.3); diameter of lower molar crown, 4.6 (3.7, 3.8, 4.0).

The teeth are much worn. When allowance is made for their condition they appear to be indistinguishable from those of the freshly killed large male Pennsylvanian *Mephitis nigra* no. 670. It is true that the lower molar of the supposed fossil is slightly larger than in no. 670 or in any other specimen of *Mephitis nigra* that I have seen. It is likewise true that the lower carnassial

is slightly wider than usual in proportion to its length, a condition that appears to be chiefly due to the advanced state of wear of its crown. Trivial dental peculiarities like these, however, especially when occurring in only one individual, cannot be regarded as important enough to establish a distinct species.

In view of all these facts it seems necessary to regard the type specimen of *Mephitis frontata* Coues (no. 2232, U. S. National Museum) as a somewhat unusual skull of the common eastern skunk and to place the name *Mephitis frontata* Coues 1875 in the synonymy of *Mephitis nigra* (Peale and Beauvois) 1796.

United States National Museum, Washington, D. C.

SYSTEMATIC STATUS OF DIPODOMYS MERRIAMI AMBIGUUS MERRIAM

By William B. Davis

In identifying specimens of the four-toed kangaroo rat collected in 1939 and 1940 in Culberson County, Texas, the writer found it necessary to compare his material with topotypes and near topotypes of *Dipodomys merriami merriami* Mearns and *D. m. ambiguus* Merriam and to study anew the relationships of these two supposed geographic races. Pertinent materials were kindly loaned by Dr. H. H. T. Jackson from the Biological Surveys Collection and by Dr. E. Raymond Hall from the collections of the California Museum of Vertebrate Zoology.

In the original description of *D. ambiguus*, Merriam (N. Amer. Fauna, no. 4, 1890, p. 43) states that it "is closely related to *D. merriami*, . . . but differs from it in having shorter ears and tail and longer hind feet. The thigh patch is very much smaller—hardly a third as large as in *D. merriami*. Unfortunately, the skull of the latter has been lost, so that no cranial comparisons can be made. The examination of specimens from intermediate localities may result in reducing *ambiguus* to subspecific rank." Eleven years later, Elliot (Synops. Mamm. N. Amer., 1901, p. 234) reduced *ambiguus* to subspecific rank, placing it as a subspecies of *D. merriami*, which status it has held to the present.

From Merriam's remarks it is evident that the material available to him was not sufficient to permit an adequate comparison of the El Paso specimens with the form from Arizona that Mearns had named a few months earlier in 1890 in honor of Dr. Merriam. In fact, Merriam had only one specimen of *D. merriami*, and that a skin only. Most of his discussion of *ambiguus* is devoted to contrasting it with *Dipodomys ordii*, a species that differs markedly from the animals in question.

The present writer had had available 10 topotypes of *D. m. merriami*, 17 topotypes of *D. m. ambiguus*, and more than 80 additional specimens of the *merriami* group from localities in trans-Pecos Texas, New Mexico, and Arizona. Although slight average color differences are discernible in the topotypical series of *ambiguus* and *merriami*, they are not constant, or even nearly constant, in specimens from stations near the type localities. For example, in Culberson County, Texas, about 100 miles east of the type locality of *ambiguus*, 2 of 48 specimens are like *ambiguus* in color; the others are as dark as, or darker than, topotypes of *merriami*. Similar conditions prevail in specimens from Southern Arizona; many of them are light colored, others are dark. The presence of scattered populations of light colored rats through

TABLE 1.—*Average and extreme external measurements of topotypes of two supposed races of kangaroo rat*

RACE	SEX	NUMBER AVERAGED	TOTAL LENGTH	LENGTH OF TAIL	LENGTH OF HIND FOOT	HEIGHT OF EAR FROM NOTCH (DRY)
Ambiguus.....	♀	4	246(240–250)	149(145–152)	38.5(38–39)	11.4(10.9–11.7)
Merriami.....	♀	6	241(234–248)	141(132–146)	36.6(35–38)	12.4(11.5–12.8)
Ambiguus.....	♂	6	249(236–261)	148(141–154)	38 (37–39)	11.9(11.1–12.3)
Merriami.....	♂	4	245(234–259)	145(140–156)	37 (35–39)	12.2(12.0–12.5)

the range usually ascribed to *merriami* is not uncommon. Likewise, populations of dark colored rats occur commonly throughout the range in western Texas and southern New Mexico usually allocated to *ambiguus*. In fact if color alone be used as a criterion, the light colored *ambiguus* could be said to occupy nearly the same general range as that inhabited by the darker colored *merriami*. In other words, no definite range of any considerable size can be assigned exclusively to the light colored rats that differs materially from that assignable to the darker ones.

On the basis of external measurements the difference between these two supposed races is slight. In *ambiguus* the ratio of

$$\frac{\text{length of tail}}{\text{length of head and body}}$$

is greater than in *merriami* (1.54, as opposed to 1.41, in females; 1.47, as opposed to 1.45, in males); the hind foot averages longer (5 per cent in females, 2.8 per cent in males); the ear averages one millimeter or less shorter. These comparisons are readily evident in table 1.

In cranial characters, as expressed in measurements, the difference between *ambiguus* and *merriami* is even less. In fact, no cranial characters have been found that serve to distinguish one from the other (see table 2).

When one considers the slight average differences in all measured criteria in the specimens at hand, the amount of individual variation in specimens from a single locality, the degree to which these measurements overlap in the two named populations (except in the length of hind food and height of ear in females), and the lack of constant color differences over a wide area, it seems apparent that he is dealing with a fairly stable, though heterogeneous, population in which small, scattered, more or less homogeneous local populations have developed. As has been observed on numerous occasions, both in the laboratory and under ideal field conditions, coat color in rodents quickly responds to isolation and the resultant inbreeding, especially when some selective factor is operating.

TABLE 2.—*Average and extreme cranial measurements of topotypes of two supposed races of kangaroo rat*

RACE	SEX	NUMBER AVERAGE	BASILAR LENGTH	WIDTH ACROSS MAXILLARY PLATES OF ZYGOMA	MASTOIDAL BREADTH	LENGTH OF NASALS	ALVEOLAR LENGTH OF MAXILLARY TOOTH ROW	WIDTH OF ROSTRUM AT WIDEST PT.
Ambiguus	♀	4	25.1 (24.9–25.4)	19.2 (18.5–19.5)	22.9 (22.5–23.5)	12.7 (12.5–13.0)	4.6 (4.5–4.8)	5.9 (5.7–6.3)
Merriami	♀	6	25.5 (25.0–25.9)	19.9 (19.3–20.3)	23.2 (22.6–24.2)	13.2 (12.8–13.6)	4.8 (4.5–5.0)	6.3 (6.0–6.7)
Ambiguus	♂	6	25.4 (25.0–25.8)	19.5 (19.0–20.2)	23.3 (22.9–23.8)	13.3 (13.0–13.7)	4.6 (4.5–4.8)	6.2 (5.7–6.8)
Merriami	♂	4	26.0 (25.5–26.4)	19.6 (19.0–20.2)	23.0 (22.6–23.3)	13.4 (12.9–13.9)	4.7 (4.4–5.1)	6.2 (6.1–6.5)

Apparently coat color in *Dipodomys* is closely associated with edaphic conditions. In Culberson County, the light colored rats were invariably found on light colored soils; the darker specimens on darker, stony terrain. According to Bailey (N. Amer. Fauna, no. 25, p. 150) the specimens from El Paso, on which the name *ambiguus* was based, were captured on sandy soil along the Rio Grande. "A series from Sierra Blanca," he states, "is intermediate and can be referred in part to this [*ambiguus*] and in part to *merriami*." There the soils are perceptibly darker than are the sands along the Rio Grande. But, as Bailey (*loc. cit.*) points out, the cranial characters throughout the group are extremely constant.

Because of the close agreement in all characters studied—in no instance are the average differences as much as 10 per cent—it seems advisable to consider *D. m. ambiguus* Merriam as merely an ecotype, developed in response to edaphic conditions, and as a synonym of the earlier described *D. m. merriami* Mearns.

Texas Cooperative Wildlife Research Unit, College Station, Texas.

GENERAL NOTES

ON THE OCCURRENCE OF SYNAPTOMYS COOPERI IN FORESTED REGIONS

In his review of the lemming mice Howell (North Amer. Fauna no. 50, 1927) remarks that *Synaptomys* is usually confined to bogs and swampy lands, and likewise occurs in dry patches of grass and other low cover. In recent communications with Dr. Eric Hill of the American Museum of Natural History, he expressed surprise that I had taken these mice in heavy forested areas, and suggested that I make available this information.

From August 6–24, 1938, I collected 12 *Synaptomys cooperi cooperi* on the Edmund Niles Huyck Preserve at Rensselaerville, Albany County, New York. These were all secured in heavy beech-hemlock woods, with a rich ground cover of ferns, *Clintonia, Maianthemum, Asarum, Actaea, Caulophyllum, Tiarella, Mitella, Geranium Robertianum, Viola Selkirkii, Aralia nudicaulis, Cornus canadensis, Chimaphila, Gaultheria, Mitchella* and *Waldsteinia*. A substantial layer of deep black leaf mold covered the ground in the immediate area where the lemming mice were tapped.

The mice were taken in runways just beneath the surface of the leaf mold. In these same burrows I collected *Blarina, Sorex fumeus, Clethrionomys gapperi, Peromyscus maniculatus gracilis* and *Napaeozapus insignis*.

Synaptomys, at least in this habitat, appears to colonize. I took 7 in one area of scarcely 600 square feet, and 5 in another area somewhat smaller. Five of these were adult males, averaging 24.3 grams, with enlarged and descended testes. Six adult females, none of which was pregnant nor lactating, averaged 21.4 grams. The only immature individual was a 9.5 gram female, which I caught in my hands while setting traps.

On October 15, 1938, I set 200 traps in a heavily wooded area in the Allegany State Park, near Red House, Cattaraugus County, New York. The following morning the traps held two *Synaptomys cooperi*, in addition to a number of *Blarina, Sorex cinereus, Sorex fumeus, Clethrionomys* and *Peromyscus maniculatus*.

Examination of the stomach contents of the August specimens disclosed a mass of undetermined green matter, a few insect remains of unrecognizable origin, and the numerous spores of the fungus *Endogone*.—W. J. Hamilton, Jr., *Cornell University, Ithaca, New York.*

THREE NEW MAMMAL RECORDS FROM KENTUCKY

During the course of recent faunal investigations in Eastern Kentucky three species of mammals apparently hitherto unrecorded from the state were collected. All of the specimens collected are deposited in the Welter Museum of Biological Sciences at Morehead State Teachers College, Morehead, Kentucky, and in the United States National Museum, Washington, D. C. The writer is indebted to Dr. Remington Kellogg for the identification of questionable forms.

Sorex cinereus cinereus Kerr. **Cinereus Shrew.**—Seven specimens of this shrew were taken near the summit of Big Black Mountain, in Harlan County, at an elevation of not less than 4,000 feet. Six of the 7 specimens were taken from runways at the sides of moss-covered logs in damp, deciduous thickets. The other specimen was taken at the edge of a dry pile of chestnut logs in an open area near a thicket. One of the specimens, collected on August 10, 1939, contained 3 well-developed embryos. The average measurements in millimeters of 4 females are as follows: Total length, 108.25 (99–122); tail vertebrae, 42.54 (38.5–50); hind foot, 13.25 (11.5–15). The measurements of 3 males are: Total length, 102.33 (88–111); tail vertebrae, 39.33 (39–40); hind foot, 12.8 (12–13.5).

Peromyscus maniculatus nubiterrae Rhoads. **Cloudland White-footed Mouse.**—This form is apparently the common white-footed mouse of Harlan County. Specimens were trapped at two localities, one at an altitude of 1,250 feet at Rosspoint, and the other

at an elevation of about 4,000 feet near the summit of Big Black Mountain a few miles from Lynch, Kentucky. Four specimens were taken at Rosspoint in rhododendron thickets along the Poor Fork of the Cumberland river. Nine specimens were taken at the summit of Big Black Mountain in dense deciduous thickets. The average measurements of 3 females are as follows: Total length, 178 (153–191); tail vertebrae, 86.67 (82–93); hind foot, 23.8 (21.5–28). The average measurements of 10 males are as follows: Total length, 155.45 (140–174); tail vertebrae, 77.85 (68.5–93); hind foot, 21.05 (20–23).

Napaeozapus insignis insignis Miller. **Woodland Jumping Mouse.**—One specimen of this animal was taken in an open deciduous woodland at an elevation of about 4,000 feet near the summit of Big Black Mountain. This area, about an acre in size, was one of the very few areas of open woodland near the summit of the mountain. Further trapping in the same and adjoining areas in 1939 and 1940 has failed to yield another specimen. The measurements of this animal, a male, are: Total length, 207; tail vertebrae, 133; hind foot, 29.—ROGER W. BARBOUR, *State Teachers College, Morehead Kentucky.*

THOMOMYS AS BURROWERS IN THE SNOW

Davis (The Recent Mammals of Idaho, 1939, p. 43) presents evidence that the distribution of *Thomomys* and certain other small mammals depend, in part, upon their burrowing through the snow across areas which are inhospitable to them in summer. Direct evidence of burrowing in the snow by *Thomomys talpoides fuscus* Merriam came to my attention at the Deer Park Guard Station on the Boise National Forest, Idaho, during the winter of 1939–40. The brown pocket gopher apparently uses the snow as a burrowing medium in three ways:

1. Snow serves as a means of "easy travel," as indicated by the following observation: While skiing across a south slope in mid-afternoon of January 14, 1940, I observed a "hump" moving in the snow and leaving a low ridge behind it which had fallen in at places, exposing a burrow. The movement ceased when I stopped about 10 feet away, and a male brown pocket gopher was caught at the "hump." The snow at this place was 8 inches deep and wet, as it was thawing. Later estimates made by timing a moving block on the floor indicated that the animal had been moving about 5 feet a minute. The tunnel left was paced off and found to be about 50 feet long (fig. 1). It began at the base of a bitterbrush and proceeded in a nearly straight line, deviating slightly to touch at two clumps of giant rye grass. The soils of the region are suitable for gophers, so there was no distributional significance to this particular observation. On January 5, 1940, a similar tunnel was observed that crossed a road from gopher diggings on one side to those on the other. This roadbed, being well packed, may have been a hindrance to the animal until the snow provided easy going.

2. Davis (*loc. cit.*) points out a second use of snow as tunnels for depositing waste materials. He mentions coils of earthen cores that are left after the snow has melted. Figure 2 shows such a coil. The animal had apparently burrowed up into the snow at least several feet, as the "strings" of earth are one above another. Densely packed plant materials, probably from underground nests, have been found in parts of coils examined last spring (1940).

3. It was found that the gophers in this area maintain open tunnels in the snow for considerable periods of time. These were found for me by an English setter pup that attempted to catch the animal by following along the snow and jumping on the spot where she thought the animal was. This was possible only where the snow was less than a foot deep, and I am sure, from observing the dog, that she was able to locate the animal by scent as it moved in its tunnel. The melting snow in the spring exposed these open tunnels. Open tunnels were found all winter, often with waste tunnels adjacent.

Thus, three distinct uses of snow as "a burrowing medium" were found to be em-

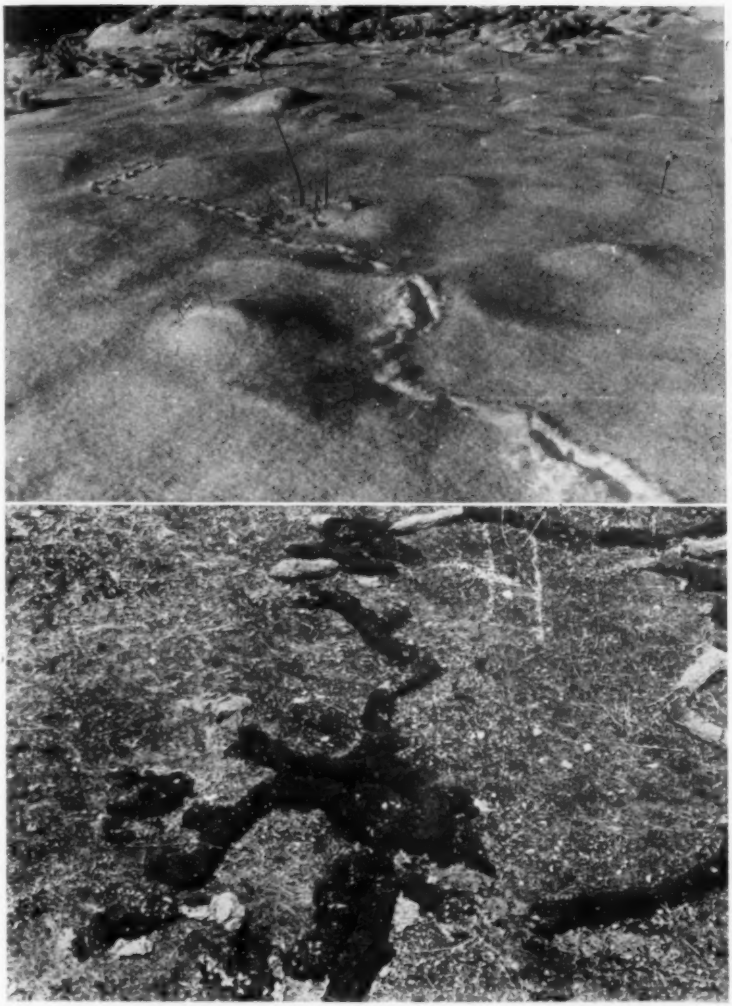

FIG. 1 (above). Thomomys burrow in snow. January 14, 1940
FIG. 2 (below). Earthen cores left by melting snow. May 22, 1940

ployed simultaneously throughout the winter.—WILLIAM H. MARSHALL, *Assistant Biologist, U. S. Fish and Wildlife Service, Boise, Idaho.*

AILURAENA STIRTON AND CHRISTIAN REFERRED TO CHASMAPORTHETES HAY

Dr. T. S. Palmer has kindly directed our attention to the fact that *Ailuraena* recently proposed by us for an Upper Pliocene member of the Hyaenidae (Jour. Mamm., vol. 21, no. 4, pp. 445–448) is preoccupied by *Aelurina* Gill, 1871. We therefore refer *Ailuraena johnstoni* Stirton and Christian to the genus *Chasmaporthetes* Hay, 1921 (Proc. U. S. Nat. Mus., vol. 59, pp. 636–637). Although we have considered Hay's type as generically indeterminate, due to its poor preservation, it seems advisable under the circumstances to establish *Chasmaporthetes* instead of selecting a new name. We have not had an opportunity to examine Hay's type but his measurements reveal some discrepancy in the size of the two species. Among other differences the carnassial in *C. johnstoni* is shorter and apparently more massive. Measurements: Length, 24.0 mm, width of anterior root, 9.0 mm, width of posterior root, 6.3 mm. Future discoveries may disclose the true relationship between the Pleistocene *C. ossifragus* Hay and the late Tertiary *C. johnstoni* (Stirton and Christian), when a detailed comparison of the dentitions can be made.—R. A. Stirton, *Museum of Paleontology, University of California, Berkeley, California, and* Wayne G. Christian, *West Texas Teachers College, Canyon, Texas.*

PREY CHASES PREDATOR

While squirrel hunting about three miles east of Auburn, Alabama on October 1st, I witnessed an unusual sight. I had just killed two gray squirrels (*Sciurus c. carolinensis* Gmelin) when I heard several more scolding from a near by tree. Creeping closer to get a shot, I heard a squirrel running along the ground toward me. To my surprise there broke into the opening in which I was standing a spotted chicken snake (*Elaphe obsoleta confinis*) approximately five feet long, with a squirrel in hot pursuit. The squirrel was darting back and forth nipping the snake in the middle of the body. Near the center of the clearing the snake stopped, the squirrel darted back and forth at the snake two or three times more then ran a short distance up the side of a nearby tree. I shot the squirrel and to my amazement it turned out to be a little fellow no more than one-fourth grown. A few moments later I heard more scolding in the direction from which the snake and the squirrel had come. On investigating I saw two young squirrels on the top of a snag that had rotted off about 15 feet from the ground.

The spotted chicken snake is a notorious predator of squirrels and is often found on large branches and in cavities in trees. I do not know whether it was chased from the den by the squirrels or whether they encountered it on the ground. In any event, the squirrel appeared to be getting the better of the snake while his litter mates watched from the top of a tree.—George C. Moore, *Cooperative Wildlife Research Unit, Auburn, Alabama.*

A NATURE DRAMA

In spite of their gregarious habits and their apparently safe underground retreats, the noisy little prairie dogs of the Great Plains have many enemies. Coyotes, badgers, bobcats, eagles, hawks, ferrets, weasels, and several species of snakes prey upon them and keep them constantly on the alert.

The larger predators naturally must catch the wary prairie dogs above or close to the surface of the ground. Badgers dig them out; ferrets and weasels descend underground to capture them; hawks and eagles must take them above ground; and snakes pursue them either below or above ground. Ordinarily, a snake will attack only a comparatively small prairie dog, as it can scarcely swallow a fully mature individual.

It is only natural that even the seemingly timid prairie dog will protect her young. A rattlesnake or bull snake that tries to get a square meal while in a prairie dog's burrow

takes great chances of being seriously mutilated or even killed. I have seen a number of dead snakes near the entrance to burrows; some of them were partially buried, but all showed signs of mortal wounds.

One day as the writer was crossing a prairie dog town his attention was drawn to a curious looking mass at the foot of a mound near a burrow. Viewed closely, this turned out to be the entwined but motionless forms of a male prairie dog and a large bull snake —dead, apparently, as the result of combat.

The snake had apparently tried to enter the prairie dog's burrow in search of food, but had been met by the protecting male dog. The soft dirt for several feet around the mound was marked in varied patterns indicating that the battle had lasted for some time. The snake had been severely bitten in a number of places, and the prairie dog looked as if it had been squeezed or choked to death. The battle had been fairly close as both had died in fighting position.—E. C. Cates, *Fish and Wildlife Service, Albuquerque, N. Mex.*

A REFLECTOMETER FOR MEASURING COLORS OF ANIMALS

In the study of variations and adaptations in animals, there has long been a need for accurately measuring differences in color. Variations in hue and brilliance, obvious to the eye, are difficult to express in terms that can be profitably compared in the absence of the animals. It is a definite advantage to be able to express the color in mathematical terms, when comparisons are undertaken of different individuals, populations, races and species of vertebrates as an aid in solving problems associated with geographic distribution, genetics, taxonomy and growth.

A machine, in several ways more satisfactory than any other of which I know, for taking readings of the kind mentioned is here described. It is based upon the principle that the light reflected from the specimen, illuminated by a constant source of diffused light, may be picked up by a photoelectric cell and registered on a galvanometer to yield a mathematical measure of the color of the specimen. A block of magnesium carbonate is used as the standard for white in computing the percentage of reflection. By means of filters a trichromatic analysis, expressed in simple ratios, may be similarly obtained.

In the reflectometer (see Fig. 1) six seasoned tungsten bulbs are operated at 6.5 volts from a storage battery. The light, diffused through sand-blasted glass and by walls covered with aluminum paint, falls on the portion of the specimen defined by the circular aperture. Only light reflected from this designated area is collected by the lens. The specimen is at such a distance that the light is brought to a focus on the photoelectric cell, and the aperture of such a size that the entire light-sensitive area of the cell is utilized. Filters are interposed in the path of light between the lens and photoelectric cell. The "Viscor" filter, incorporated in the photoelectric cell, eliminates the ultraviolet light and the great excess of infrared radiations, and further corrects the transmission to approximately the standard visibility curve (I.C.I.). A "Daylite" filter corrects the radiant energy from the tungsten lamps to approximately the equivalent of sunlight. Three removable filters, carefully tested and balanced for this particular type of color analysis, limit the portion of the spectrum observed at any one time to a blue, a green, or a red region. The current generated by the illuminated photoelectric cell is registered on the galvanometer in millimeters of deflection. A calibrated shunt resistance, designed for this particular photoelectric cell and galvanometer, divides proportionately the generated current delivered to the galvanometer so as to give even ratios. The deflection of the galvanometer is proportional to the luminous flux reflected from the specimen. Readings for red, green and blue are obtained with the corresponding filters in place. The specimen readings are compared with corresponding values taken on the white standard to give the percentage of reflection.

One use which has been made of this reflectometer is to measure differences in brightness and hue in geographical color-gradients of different kinds of mammals. It is designed to accommodate flat mammal skins as well as the conventional round study-skins of mammals and birds up to those of pocket gopher- and quail-size. Samples of soil and other material can be inserted on a watch glass or small tray. Parts of larger skins or other big objects can be accommodated by removing the base of the reflectomoter (see dowel in Fig. 1) and setting the instrument directly upon a selected area.

The efficiency of the reflectometer depends on the proper performance of each unit as well as on the integration of all of the units. The attainment of a satisfactory linear response to the amount of light has been made possible by the proper selection of avail-

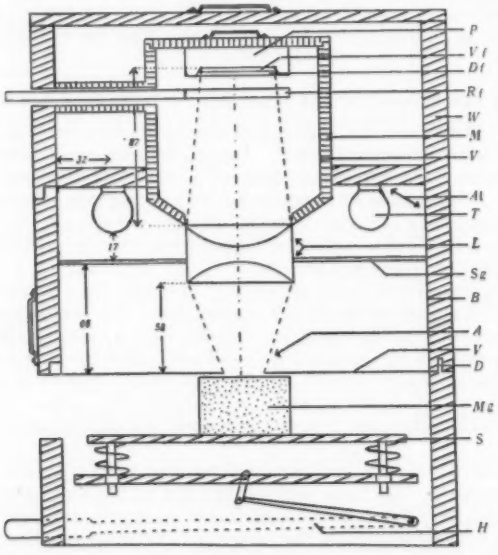

FIG. 1. Diagram of cross section of reflectometer. Scale: quarter size. Measurements in millimeters. P, photoelectric cell; Vf, "Viscor" filter; Df, "Daylite" filter; Rf, removable filter; W, wood; M, masonite; V, black velvet; Al, aluminum paint; T, tungsten lamp; L, lens; Sg, sand-blasted glass; B, black paint; A, aperture (31.5 mm.); D, dowel; Mg, magnesium carbonate block; S, stage, H, handle.

able optical and electrical units and their calibration, and finally, when necessary, by the introduction of correction factors. Although the present experimental model is not a precision instrument, accuracy was attained in all components high enough to make the instrumental errors small when compared with the variations occurring in the specimens.

Accuracy in taking readings is increased by following a cycle of procedure adapted to the material whose color is being measured. Constant voltage must be maintained at the bulbs. Marked changes in the temperature of the cell disrupt the actual and relative readings. When the instrument is operated for several consecutive hours a forced draft cooling system becomes necessary.

For assistance with construction of the reflectometer, I am indebted to many persons at the University of California. Of these, Mr. John E. Gullberg, in particular, gave invaluable assistance. Professor Raymond T. Birge and his associates generously permitted the use of their exceptional shop facilites, and aid in calibration was given by Messrs. Frank A. Ryder, Arthur R. Collins, Albert R. Champion and Professor Gordon Mackinney. I am also grateful to my major professor, E. Raymond Hall, for facilities provided at the California Museum of Vertebrate Zoology.

The following data relative to materials used will be of aid in any attempt to duplicate the instrument:

Storage battery, 8 volts, 145 amperes per 20 minutes capacity.

Battery charger.

Carbon rheostat, .1–8 ohms, 200 watts load capacity.

Knife-switch.

Voltmeter, range 0–8 volts, least count .2 volts.

Six tungsten lamps, Mazda no. 1130, 6–8 volts, 21 candle power.

Sand-blasted glass, 8 x 8 inches square.

Projection lens consisting of 2 equal 60 mm plano-convex lenses mounted with plane faces 30.8 mm apart. When stopped down, parallel rays are brought to a focus 28.5 mm from the nearer lens.

Corning glass filters, 2 inches square, polished: blue no. 502; green no. 349 and 978 Std. T.; red no. 246; "Daylite" no. 590 (fitted into window of photoelectric cell).

Photoelectric cell, Weston "Photronic", Type 1, with "Viscor" filter.

Variable shunt resistance with the following position values: 1, open; $\frac{1}{2}$, 1081 ohms; $\frac{1}{4}$, 360 ohms; $\frac{1}{10}$, 120 ohms; $\frac{1}{100}$, 10.9 ohms.

Rubicon galvanometer, no. 3403 HH; resistance 1081 ohms; external critical damping resistance 10,000 ohms; sensitivity .003 microamperes per mm; period 1 second.

Magnesium carbonate block (U. S. P.).—FLOYD E. DURHAM, *California Museum of Vertebrate Zoology, University of California, Berkeley.*

AN OBSERVATION ON THE NEST-BUILDING BEHAVIOR OF THE OPOSSUM

Early in the morning of August 4, 1938, I had an opportunity to watch at close range an opossum in the act of gathering and transporting leaves presumably for an underground nest. I was hunting squirrels in the woods of Bollinger County, in southeastern Missouri, when my attention was attracted by a rustling in the dry leaves close by. The noise was made by a young opossum slightly more than half grown. The animal came out of a hole in the ground about eight feet from where I stood and proceeded to select small mouthfuls of two or three leaves each. The leaves were taken out of the mouth with the forepaws and passed back along the abdomen to a position in front of the thighs. There they remained momentarily while the front feet were placed on the ground and the hind feet were brought up to take them and slide them along the tail into a loop in that member, which is ordinarily thought of as a means of support by suspension but which in this case was sustaining the hind quarters above the ground while the hind feet were being used to place the leaves in the loop.

About six or eight mouthfuls were handled in this way. The action was rapid, and the leaves were in almost continuous motion from the time they were picked up from the ground until they came to rest in the coil of the tail. After the loop was filled, the opossum chose a last mouthful and, with its tail extended almost horizontally except for the loop which held the bundle of leaves, proceeded into the hole in the ground.

Soon the animal returned, and when it first came up the tail was nearly straight with the end dragging on the ground. When the first leaves were picked up, the loop was formed in the tail, and the process of gathering a bundle of leaves was repeated. The opossum made four trips in about ten minutes. It paid no attention to me, although

it faced me in returning to the hole. At no time was the animal more than fifteen feet away. I wished heartily for a motion-picture camera.

During its fifth trip for leaves, I walked over and put my foot in the hole from which it had emerged. The animal dropped the unfinished roll of leaves, bristled, and advanced to attack, snarling and showing its teeth. It snapped my shoe, which I extended, and after more snarling turned and ran clumsily though quite rapidly away, presumably to another burrow.—LUTHER SMITH, *Department of Field Crops, University of Missouri, Columbia.* (Missouri Agricultural Experiment Station Journal Series, no. 696.)

A FAR SOUTHWESTERN OCCURRENCE OF PITYMYS IN TEXAS

Two subadult and one young *Pitymys* (Mus. Vert. Zool. catalogue nos. 91024, 91025, and 91027) were taken 3 miles south of Kerrville, Kerr County, Texas, in February, 1940. They were found in a locality where buffalo grass (*Bulbilis dactyloides*) and other grasses are abundant. Spanish oak (*Quercus texana*) occurs in an open stand in the area, and redbud (*Cercis reniformis*), cedar (*Juniperus* sp.), and sumac (*Rhus lanceolata*) are sparsely represented. Several years ago many of the trees were cut or pruned and the brush was piled in open spaces. The *Pitymys* were taken in the grass at the margin of the piles, where surface and underground runways were present. The area had been heavily grazed by livestock and the tall grass essential to the rodents was limited to the protected places. The specimens resemble *P. nemoralis* more closely than *P. pinetorum auricularis*. The upperparts are light chestnut in color with a suffusion of black tipped hairs over the back and rump, the belly is pale buff on a plumbeous background, and the tail is bicolor. The ears are from 10 to 11 millimeters long. *Pitymys* has been previously reported in Texas from Barron Springs, about 30 miles northeast of Kerrville, and from Jefferson (Bailey, N. Amer. Fauna, no. 25, p. 120).—MONROE D. BRYANT, *California Museum of Vertebrate Zoology, Berkeley, California.*

SOME MAMMALIAN ECTOPARASITES

The following ectoparasites and their mammalian hosts were collected during a survey of the vertebrate animals of the Friant Reservoir basin, located 20 miles north of Fresno, Fresno County, California. This area will be inundated with the completion of the Friant Dam, a unit of the Central Valleys Water Project, which is now under construction:

Host	*Parasite*
Myotis californicus	*Mydopsylla* sp.
Antrozous pallidus	*Basilia* sp. near *dunni*
Antrozous pallidus	*Spinturnix* sp.
Mephitis mephitis	*Hippelates* sp.
Mephitis mephitis	*Neotrichodectes mephitidis*
Mephitis mephitis	*Pulex irritans*
Citellus beecheyi	*Diamanus montanus*
Citellus beecheyi	*Hoplopsyllus anomalus*
Thomomys bottae	*Geomydoecus californicus*
Peromyscus maniculatus	*Hoplopsyllus anomalus*
Peromyscus maniculatus	*Malareus telchinum*
Peromyscus boylii	*Dermacentor* sp. (probably *occidentalis*)
Peromyscus boylii	*Eubrachylaelaps* sp.
Peromyscus truei	*Cyclolaelaps circularis*
Neotoma fuscipes	*Cuterebra* sp. (probably *buccata*)
Neotoma fuscipes	*Laelaptinae* sp.
Neotoma fuscipes	*Orchopeas sexdentatus*
Sylvilagus audubonii	*Haemaphysalis leporis-palustris*

Thanks are due to Dr. F. C. Bishopp, H. E. Ewing, E. C. Cushing, C. F. W. Muesebeck, C. T. Greene, H. L. Trembly and Alan Stone of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, who kindly identified these specimens. A comprehensive report on the results of this survey is now being prepared for publication.—Douglass H. Hubbard, *Department of Fish and Game, Agricultural and Mechanical College of Texas, College Station, Texas.*

HIBERNATION OF EPTESICUS FUSCUS IN A NEW HAMPSHIRE BUILDING

The following observation of the successful hibernation of a big brown bat, *Eptesicus f. fuscus*, in a building, is of interest because the bat was at all times in an environment such as it might easily have selected for itself. The creature was first observed during the last week of November, 1939, hanging to the closed blind of an attic window at New Durham, New Hampshire. Realizing the impossibility of keeping track of the animal in this rather typical New England attic led to its transfer to an unheated bedroom. Even here its movements about the room were frequent and it was constantly being lost, so during the middle of December the bat was placed in a tight wire cage. This was left in the bedroom for about two weeks, during which time the bat remained completely motionless as far as could be determined.

The cage was then hung in an unheated cellar the temperature of which remains quite uniformly between 34–42 degrees F throughout the winter months. A small dish of water was placed in the cage with the animal. Observations at frequent intervals showed that the creature moved about quite often and also occasionally went down to drink. Once during the first week of February it became sufficiently active to squeak quite vigorously for a short time. Subsequent to this outburst it became quiet and indeed seemed to be dead, becoming quite emaciated as time went on. But late in March it again became mildly active, shifting its position, but always hanging head downward, and drinking often.

Finally in early May it became quite vigorous. The weather outside then being fairly warm, cage and captive were carried to an open shed late one afternoon. Quickly the creature opened its wings, crawled from the cage, spread them and was soon seen flying about and apparently searching for food. Before its release the bat was banded to make possible identication if found again.

This is the third case of hibernation of the brown bat in the New England states I have known. The other two occurred in Gorham, Maine. In these two cases the bats were hibernating in houses. Since it was impossible to follow them through hibernation till spring came, no particular records were kept. Swanson and Evans (Jour. Mamm. vol. 17, pp. 39–43) and Wetmore (*ibid.* vol. 17, pp. 130–131) have also reported hibernation of *Eptesicus* in buildings or under conditions closely simulating those which bats could find in buildings.

Hibernation was far from being one long unbroken sleep for the bat that wintered in my attic and cellar. Nevertheless, its fat reserves were adequate to support this activity in addition to its lowered resting metabolism from late November to early May. —R. M. Whelden, *Biological Laboratories, Harvard University, Cambridge, Mass.*

COYOTE RUNS AMUCK

People who spend a great deal of time in the wide open spaces and fail to observe wild animals closely rarely appreciate the full significance of the expression "survival of the fittest." The strife between wild animals and their enemies can often be witnessed by man be if he learns to become keenly observant while out-of-doors.

Wild animals not only have to hold their own with those of other species but they also frequently battle for their rights within the family circle. Mating season brings strife among vigorous males of a species, and forces females to protect their young. In

addition, both males and females are always on the alert to attack traditional enemies, either for self-protection or in search of food.

Early one bright morning in May, several years ago, the writer was riding a horse through some rough and barren hills just east of Powder River in southeastern Montana. At that time of the year coyotes were "denned up" in the rough breaks, caring for their young. It is always interesting to find a den of coyote pups and very amusing to watch the female endeavor to lead a person away from her young. A careful watch was kept, therefore, for signs indicating the presence of a coyote family in the vicinity.

Topping a steep little hill called for a moment's pause to let the pony catch up with his breathing. Before the horse had fully responded to the touch of the reins calling a halt, a drama was in the making on a stage below. A flash of dull yellow and gray was streaking up through the sage brush in a nearby coulee. The animal shot out in the clear not fifty yards away and in spite of its speed was instantly identified as a small female coyote that was undoubtedly suckling a litter of young. Close behind the fleeing female bounded a large male coyote, wild-eyed, with mouth open, and with shoulder hair standing on end as on an angry dog. The pursuing villain soon overtook the luckless female. He grabbed her by one hind foot and threw her five or six feet. Before she could get out of his way he grabbed her by the neck and shook her so hard that a mouthful of hair came loose. The completely cowed and pitiful little female dodged the next furious onslaught and ran directly towards me. The male started after her again, but suddenly both animals saw horse and rider and dodged into a nearby washout to be seen no more.

This is the first coyote "battle of the sexes" the writer has ever witnessed in spring, the females usually being well protected by her mate at that season. It is doubtful that these coyotes were mates, however, but that cannot be definitely stated.—E. C. CATES. *Fish and Wildlife Service, Albuquerque, N. Mex.*

REVIEWS

Schuchert, Charles and Clara M. LeVene. O. C. MARSH: PIONEER IN PALEONTOLOGY. Yale University Press. 1940. 541 pp., 30 pls., 33 figs.

Marsh's name is firmly linked with the discoveries of dinosaurs in the West and especially with the magnificent collection of their remains that he made for Yale University, yet the authors tell us that his original interests were in fossil mammals and that it was his first intention to devote his studies to them. Although only one of his three important memoirs is on mammals, yet out of his 270 publications, 85 are on mammals and this is not a small proportion considering the preponderance of reptile material.

It is true that some of his names were antedated by those of Leidy and Cope but there is still an impressive array of them. A great deal of Marsh's less striking fossil mammal material was set aside after the first brief descriptions had been issued, until the more imposing objects were disposed of. Much of it indeed was worked out and placed on exhibition by his successors. But his material illustrating the evolution of the horses was of great importance, especially in the widespread discussion of evolution at the time of Huxley's lectures. Two other families that he contributed to notably were the Dinocerata and the Brontotheres.

Even at the height of his dinosaur collecting, when Hatcher was sending back the skeletons of Ceratopsia literally by the carload, Marsh telegraphed him to stop work on dinosaurs and devote himself altogether to seeking for the tiny jaws and teeth of Cretaceous mammals, which were just beginning to be found in the Laramie beds of Wyoming. The result of his urgent instructions to all his collectors is to be seen in the largest collection of Mesozoic mammals in the world at the Peabody Museum of Yale University.

The first discovery in 1878, a broken jaw with a single tooth, found at Como Bluffs, Wyoming, became the type of *Dryolestes priscus*. Marsh believed it to represent a marsupial allied to the existing opossums. The next year Marsh himself found his type of *Stylacodon gracilis* (now referred by Simpson to Owen's *Amblotherium*). In all, one quarry at Como furnished about 250 specimens of jaws or teeth.

At the time of Marsh's address before the American Association for the Advancement of Science at Nashville, Tennessee, in August 1877, he believed the marsupial stock to be the ancestral stock of the placentals. In an article of September 1880, Marsh wrote: "With the exception of a very few aberrant forms, the known Mesozoic mammals may be placed in a single order, which may appropriately be named Pantotheria. . . .The generalized members of this order were doubtless the forms from which the modern specialized Insectivores and Marsupials, at least, were derived."

The wealth of Mesozoic mammal material collected by Marsh for Yale University was later (1929) monographed by Dr. George G. Simpson, who also monographed all the Mesozoic Mammalia in the Geological Department of the British Museum (1928).

Marsh laid great stress on the importance of finding Cretaceous mammal remains in this country but when found they were so fragmentary that classification was difficult. Marsh's 19 genera and 37 species were based on isolated tooth and jaw fragments and his method of classification, that of naming different types of teeth, broke down from the great numbers of types that eventually had to be grouped as different parts of the same type of dentition. However, Osborn's system of naming only whole jaws also had its shortcomings, according to Simpson, who found neither method satisfactory and "a revision in the strict sense, impossible."

The authors conscientiously list all the groups of Cenozoic mammals on which Marsh described species and genera, following with a more detailed account of his work in each group. The most important paper on the mammals was his monograph on the Dinocerata, appearing in 1886 in the Survey edition. The Dinocerata was one of the groups

around which the rivalry of Cope and Marsh raged so violently, each striving to outstrip the other in discovery and publication, each hotly contesting the claims made by the other.

Marsh was perhaps the first close student of brain evolution from the side of palaeontology. He required his preparators to clean out the brain cavity of fossil skulls and make a gelatine mold from which permanent models could be cast. His studies on these braincasts enabled him to form generalizations on the growth of the brain in geologic time, which he presented before the Connecticut Academy of Arts and Sciences in New Haven, June 17, 1874, and again in augmented form in his monograph on the Dinocerata. He showed that there had been a gradual increase in the size of the brain in Tertiary times, especially in the upper portion (the cerebral hemispheres), and that this continued increase in size was accompanied by a growth in mentality from reptiles to man. Geikie credits him with being the first "to institute any systematic inquiry into the laws which governed, and the causes which acted upon, brain-growth in these ancient animals" (the Dinocerata).

The critical student who sincerely desires to find out how much Marsh owed to members of his staff and how much really originated with himself will find ample material in this book. Among his assistants from time to time were men who subsequently became famous scientists on their own merits, including George Bird Grinnell, Oscar Harger, George Baur, Samuel Wendell Williston, William Constantine Beecher, and J. B. Hatcher. It has been alleged that Marsh owed a great deal to his assistants, especially in the ideas set forth in the Dinocerata and Odontornithes memoirs. In each case the authors take great pains to give a truthful account of Marsh's relations to these individuals so far as known. In general the evidence tends to show that although Marsh did not permit them to work independently in his field, yet he was within his contract rights in using the results which his assistants had worked out in his laboratory.

The authors also give much evidence relating to the long and regrettable controversy between Cope and Marsh. Fortunately their successors did not continue this quarrel and coöperation between different museums of palaeontology has become very close.

Those who have frequently had occasion to study Marsh's type descriptions with the specimens before them must in fairness feel that he had a real eye for diagnostic characters, especially such as would be likely to yield new orders, families, genera and species; and a decided flair for brief descriptions, which were, however, often discreetly silent at strategic points.

In spite of everything derogatory that has been said, Marsh had the great merit of being an indefatigable collector of imposing and beautiful objects of nature and art and in the end he left behind him a notable series of contributions to natural science and a noble and inspiring Museum which is still sustained by the results of his wise foresight and indomitable labors.

This book is much more than a biography of Marsh, however; it is a panorama of the times, its scenes passing from the classrooms of Yale University in its early days to the badlands of the West and to Washington in the stormy days of the establishment of the Geological Survey. Marsh's uncle, George Peabody, the benefactor of Yale and Harvard, of the poor of London and of his numerous relatives, is admirably portrayed. Marsh's collectors make a lively chapter, especially J. B. Hatcher, a most picturesque and keen collector who later became famous for his explorations in Patagonia.

This reviewer cannot close without a hearty tribute of admiration to the two authors of such a fair and dispassionate presentation of a controversial subject. Out of their sincerity and scrupulous reporting has grown a delightful book.—WILLIAM K. GREGORY.

Allen, Glover M. THE MAMMALS OF CHINA AND MONGOLIA. Part 2 of Vol. XI of Natural History of Central Asia. Pp. xxvi + 621–1350. Illustrated. American Museum of Natural History. $10.00.

The second and final part of this large work (1350 quarto pages) fulfills expectations warranted by the first, (reviewed in Jour. Mamm. vol. 20, p. 113, 1939). The groups covered are the Simplicidentata, Artiodactyla, Perissodactyla, and Sirenia. These include 256 species and subspecies, of which 210 are rodents. It is thus approximately equal to Part I in size and number of forms treated, but it is safe to assume that it represents the examination of a much larger number of specimens and a greater amount of research. As elsewhere, the small rodents offer many confusing problems only solvable when ample material is available. When the material is scanty, the resort is to opinion and Dr. Allen has not hesitated to use his unequalled knowledge of his subject to come to conclusions which are at least the best possible at the present time. The thoroughness and fairness with which every case is dealt gives confidence that no bit of evidence has been overlooked. A question often to be decided is that of specific or subspecific distinction of two named forms generally similar but geographically removed from each other. Dr. Allen tends most frequently to accept the slight assumption necessary for the subspecific status and usually his position is obviously the proper one. The history of knowledge of relationships, especially among rodents in better known regions, has proved that such an assumption is by far the most likely one. The wholesale reduction of species to subspecies as advocated by some European authors, however, is far from the careful results shown in this work, and no doubt equally far from the facts. On the other hand, species are realities, as now known from both taxonomic and experimental studies, and they may resemble each other very closely and occur in close juxtaposition, so it is possible to make mistakes.

If we were to comb this great work from end to end, as some reviewers seem to delight in doing, doubtless an array of minor exceptions might be taken. A few such, resulting from random sampling here and there, may perhaps be permissible. Thus it can be said that the comparison (p. 756) of the small hamsters of the genus *Cricetulus* with the American white-footed mice of the genus *Peromyscus*, while somewhat justifiable, might better have been made with our grasshopper mice of the genus *Onychomys* which in external appearance and habitat preferences are exceedingly similar to *Cricetulus*. The Asiatic analogue of *Peromyscus*, as of course Dr. Allen states elsewhere, is *Apodemus*. The statement (p. 646) that the squirrels of the genus *Dremomys* "are arboreal in contrast to the rock-living genus, *Sciurotamias*" is possibly open to question. In a rather brief experience with *Dremomys* in Indo-China, I found it not wholly terrestrial but largely so. Although confined to forested regions, it kept close to the ground, running along logs, perching on stumps, or scurrying through thick undergrowth. Occasionally it was seen in small trees, but never far from the ground. The contrast between it and the other squirrels of the same forest was marked and to an American somewhat paradoxical. *Dremomys*, which looked like a red squirrel, acted like a chipmunk; whereas *Tamiops*, which looked like a chipmunk, was never seen except up in the trees. If these habits are general in *Dremomys*, perhaps they should be regarded as confirming the structural characters suggesting its relationship to *Sciurotamias* and *Rupestes*.

In his treatment of the difficult genus *Tamiops*, of which I made an extensive study a few years ago, I find myself in general agreement but on some points it seems possible he may have gone a little beyond the returns. For this I may be partly responsible, since in finding three species living together in Tonkin, I was at considerable and perhaps unnecessary pains to find characters distinguishing at least two in Fukien. His conclusion that "*monticola*" and *maritimus*, of Fukien are indistinguishable may be quite correct, but this does not alter the fact that *maritimus* and *olivaceus* live side by side in Tonkin and are quite distinct from each other. That both of them can be subspecies of *swinhoei* seems highly improbable. In *Dremomys* a similar situation exists. Two species clearly occur in Tonkin, if not actually together at least in contiguous territory. One of these is *rufigenis* and the other *gularis*. Some assumption is required to connect

gularis with *pyrrhomerus*, but if we connect *refigenis* with *pyrrhomerus*, as Allen is inclined to do, we leave *gularis* distinct from both.

The accounts of the ungulates, including the numerous game animals of the region, will be welcomed in all quarters. In addition to descriptive and technical matter, there are full historical treatments of each and carefully selected quotations covering habits and methods of hunting. The conclusion that the so-called "Altai 'Wapiti' " is closely allied to the Red Deer rather than to the American Elk or Wapiti doubtless will meet with general approval.

Like its predecessor, Part 2 is illustrated with exceedingly useful distribution maps, forty-one in number. In addition there are eight text figures, illustrating dental and cranial characters, and eleven half tone plates principally showing dead game animals as brought down by members of the Asiatic Expeditions. A very full and somewhat discriminative index covers both Parts 1 and 2 which are consecutively paged.

The least that can be said of this work is that it merits the highest praise. That it will become a classic in the literature of mammalogy is quite certain. It is the fruition of years of well-directed effort both in exploration and in research. When the Asiatic expeditions began, knowledge of the mammals of our greatest continental area was unconnected and chaotic. It is here placed on a firm foundation upon which we can build with comparative ease, progress being dependent mainly upon further exploration. —WILFRED H. OSGOOD.

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OBITUARY NOTICES

GLADWYN KINGSLEY NOBLE

1894–1940

At the age of forty-six, Dr. Gladwyn Kingsley Noble died on December 9, 1940. From 1928 until his death Dr. Noble was directing the activities of the departments of Herpetology and Experimental Biology at the American Museum of Natural History.

Born at Yonkers, New York, September 20, 1894, Noble attended Harvard University where, as a student, he formed a close friendship with Dr. Thomas Barbour, who inspired him with a life-long interest in the out-of-doors, the two collaborating on a number of papers on birds and reptiles.

Receiving the A. B. degree at Harvard in 1917 and the M. S. degree a year later, in 1919 Noble accepted a position as Assistant Curator in the Department of Herpetology at the American Museum of Natural History. While in New York he attended Columbia University, receiving the degree of Doctor of Philosophy in 1922. In the same year he was appointed Associate Curator of Herpetology at the American Museum of Natural History, and in 1924 he was appointed Curator, which position he held until his death.

Dr. Noble had wide interests in the field of Natural Sciences. He took an active part in many scientific societies other than in his specialized fields of Herpetology and Experimental Biology. He became a member of the American Society of Mammalogists in 1926. He was a corresponding member of the Zoological Society of London, associate editor of the *Journal of Morphology*, and one of the editors of *Biological Abstracts*.

His 182 scientific papers, published in the short span of 27 years, coupled with the extraordinary growth and development of the two departments that he directed at the museum, bear witness to the fact that Noble was indeed no ordinary individual. The entire scientific world has lost a valued colleague.—WILLIAM B. DAVIS.

RAYMOND PEARL

1879–1940

The field of science lost a great leader in the sudden death of Dr. Raymond Pearl November 17, 1940. In addition to contributing numerous papers on his own researches, mainly in the field of population studies, he was the founder and editor of *Human Biology* and *The Quarterly Review of Biology*.

Born at Farmington, New Hampshire, June 3, 1879, Pearl attended Dartmouth College where he received inspiration and guidance from such leaders as H. S. Jennings and William Patten. Graduating in 1899, he accepted an assistant professorship in zoology at the University of Michigan, where he received the degree of doctor of philosophy in 1902. Later studying in London, Leipzig, and Naples, he returned to the United States in 1907 to head the department of biology at the Maine Agricultural Experiment Station. In 1918 he was appointed to the staff of the Johns Hopkins University, where he remained until his death at the age of 61.

Although Dr. Pearl contributed little to the specific field of mammalogy himself, his keen interest and enthusiasm in the study of animal populations led to fruitful contributions on the part of his associates.—WILLIAM B. DAVIS.

COMMENT AND NEWS

BARBOUR APPOINTED TO ADVISORY BOARD

Dr. Thomas Barbour, Director of the Harvard University Museum and of its Museum of Comparative Zoology, has been appointed to membership on the advisory board of the National Park Service. The new member, an authority on the geographic distribution of reptiles and amphibians, has made extensive zoological explorations in the Orient, the West Indies, and in Central and South America. He is custodian of the Harvard Biological Station and Botanical Garden at Soledad, Cuba, chairman of the executive committee of the Institute for Research in Tropical America, and a Life Member of the American Society of Mammalogists.

EACH MEMBER HAS RESPONSIBILITY

As your Corresponding Secretary has repeatedly stressed, one important objective of the Society is to increase its membership. This can be accomplished only by the concerted efforts of ALL members. Each member should make it his responsibility to secure at least one new member each year.

The Corresponding Secretary has available a supply of a printed prospectus, suitable to be mailed to prospective new members, and the necessary application blanks, which can be had for the asking.

ANNUAL MEETING

The annual meeting will be held at the Field Museum, Chicago, June 9–13. One session has been reserved for a panel discussion of Population Studies in Mammals, a timely subject in view of the increased interest in management and biological control of both desirable and undesirable species.

Headquarters will be the Stevens Hotel; make your reservation early. Special rates are available to students who plan to attend the meeting.

EFFICIENT TRANSLATING

Mr. A. S. Loukashkin, a member of the Society residing at 1565b Scott Street, San Francisco, California, recently from Harbin, Manchuria, is prepared and qualified to translate works in Russian, German, Japanese, and other languages for specialists. Those of you who have translating jobs to be done might do well to get in touch with Mr. Loukashkin.

TO PROSPECTIVE MEMBERS OF THE AMERICAN SOCIETY OF MAMMALOGISTS

As stated in the by-laws, the objects of the Society are "The promotion of the interests of mammalogy by holding meetings, issuing a serial or other publication, aiding research, and engaging in such other activities as may be deemed expedient."

So far the Society has vigorously pursued these objectives. The meetings have been held regularly, and are becoming more important yearly. These are attended by many of the leaders in the field of mammalogy. In addition, the Society has been active, and is influential, in many conservation projects.

One of the most important functions of the Society is the publication of THE JOURNAL OF MAMMALOGY. This journal has been published quarterly now for some 20 years, and it has become indispensable to all professional mammalogists, wildlife managers, naturalists, sportsmen, and others interested in mammals. The Journal is the only one in North America devoted entirely to mammalogy, and it holds high rank as a scientific publication, as do the monographs, which constitute a second series sponsored by the Society. These publications have aided and stimulated research in mammalogy. Many articles in the field of game and wildlife management have appeared.

While this Society and its publications give a somewhat different slant on the scientific situation from those of the WILDLIFE SOCIETY and similar organizations, they nevertheless are of the utmost value to anyone interested in mammals, whether from the game management or the naturalistic standpoint.

Annual dues, which include a subscription to the Journal of Mammalogy, are $3.00. Any member has the right to attend meetings, participate in the activities of the club, and hold office.

Apply to the Corresponding Secretary for application blanks.